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MEMORANDUM

To: Lisa Kuzniar and William Gwilliam
DOE/NETL, Morgantown, West Virginia

From: Deborah R. Hutchinson
USGS, Woods Hole, Massachusetts

Subject: ***Quarterly Status Report for Second and Third Quarters, FY2003***
Task No. 5, Processing and Evaluating Data for Gas Hydrates, Gulf of Mexico
Master Interagency Agreement No. DE-AI21-92MC29241, task number DE-AT26-97FT34343

Date: 20 August 2003

Work this Quarter:

(1) ***Gulf of Mexico May Seismics Cruise:*** Several planning meetings held in the second quarter laid the groundwork for the very successful 14-day cruise in May, 2003 to collect high-resolution seismic-reflection profiles in the northern Gulf of Mexico. More than 1,000 km of high-resolution multichannel seismic reflection profiles were acquired in two areas where potential hydrate drill sites have been identified (around lease blocks Atwater Valley 14 and Keathley Canyon 195). The multichannel data were processed at sea, including geographic coordinates for the geometry in the header entries of the seismic data, enabling computer interpretation to begin upon return from the cruise. Preliminary results from the data indicate that detailed structures beneath hydrate mounds/vents and in the vicinity of the Bottom Simulating Reflection (BSR) are visible in the data. Variable amplitude strength and geometric relations of the reflections show many good indicators of hydrate occurrence and provide potential targets for the August cruise and eventual drilling. On 1 June, a summer student in Woods Hole began working on interpreting the data from the Atwater Valley site. The attached cruise report gives more details about the field operations and preliminary results (*see Attachment 1*).

(2) ***Preparation for Gulf of Mexico August Geophysics Cruise:*** In support of determining sampling and profiling sites for the August cruise, results from the May cruise were used to generate maps, preliminary interpretations, and seismic sections. These were distributed to

project participants (including members of the JIP) and formed the basis for conference calls in which decisions about specific site locations and cruise objectives were decided. Participation in final cruise plans is scheduled to occur in July, at the 22 July Chevron/Texaco JIP meeting.

(3) ***GHASTLI Laboratory Results (Woods Hole):*** Construction of end caps capable of measuring s-wave velocities in GHASTLI are under construction. While s-wave measurements have been in GHASTLI in the past, they have been extremely noisy and not very useful. These new endcaps are being designed to have better signal to noise ratios. These end-caps will also measure p-wave velocity. After completing the s-wave sensor installation, the end caps will also be modified to include electrical resistivity measurements. Calibration and testing of the end caps will take place in synthesized samples prior to making measurements on preserved Mallik-5L samples.

(4) ***Petrophysics Laboratory Results (Menlo Park):*** At the request of the Maurer/Anadarko JIP, a suite of rapid depressurization experiments on pure methane hydrate and methane hydrate + quartz mixtures were performed at elevated pressures, to determine optimum preservation conditions. An additional sample of porous methane hydrate was dissociated following a slow depressurization pathway that emulated depressurization during retrieval of a drill core sample. A sample of mock-drill-core material (methane hydrate plus sediment) was also fabricated in our lab and sent to the Anadarko Mobile Laboratory for testing of recovery techniques. Results from all tests were sent to Anadarko researchers in early March, and provided recommendations for optimizing hydrate preservation by control of mud temperature during drillcore retrieval. The Anadarko group were in fact able to preserve bulk portions of our shipped sample material in their Mobile Laboratory by our recommended procedures. Based on this success and our previously-published results, they have invested in a computer-controlled mud-temperature regulating system to aid in the optimal recovery of hydrate-bearing material at the actual drill site. These experimental results were also formally presented by Steve Kirby at the March 24-26 Maurer/Anadarko JIP Advisory Panel Meeting meeting in Anchorage and summarized in a report to the Maurer/Anadarko JIP dated March 4, 2003 (*see Attachment 2*).

(5) ***Marion Dufresne Giant Piston Coring Results:*** Analysis and interpretation of core material collected during the 2002 cruise continued during these two quarters. This consisted of gas analyses, water content analyses, sediment grain analyses, and sediment grain density analyses on approximately 150 samples. Manuscripts describing the preliminary results are being assembled by cruise participants and will be published as a USGS Digital Data Series (DDS) electronic publication. These results were distributed to collaborators during the April AGU-EGU-EGS meeting in Nice, France. The subcontractor's report on heat flow results was received and will be included in the DDS. Extensive SEM imagery on the cores that contain hydrates have been completed and compared with imagery collected from dissociation experiments on synthetic samples (i.e., known) samples that were exposed to similar ocean-floor conditions.

(6) ***New XRD Apparatus***: The new precision Rigaku X-ray diffractometer with theta-theta goniometer and Jade "Plus" software was installed in Menlo Park in February. The design

of a cryogenic stage for this instrument is now complete, and it is currently being manufactured in the USGS machine shop. This accessory will allow routine low-temperature XRD analyses of gas-hydrate powders or intact samples. This cryosystem will be available for initial testing in early May. Our volunteer Marianne Okal did the design work for this cryostage.

(7) ***Deformation and Strength Characterization of CO2 and Methane-Ethane Hydrates:*** Samples of sI CO_2 hydrate and sII methane-ethane hydrate were synthesized in the Menlo Park lab in January, February, and March, then transported to Lawrence Livermore National Laboratory for deformation and strength testing. Initial results show that both hydrates exhibit significantly different strength behavior than pure methane hydrate, suggesting that the guest molecule plays a more important role than previously anticipated.

(8) ***Congressional Briefing:*** At the request of Myron Nordquist, a staffer to Senator Conrad Burns, D. Hutchinson participated in a briefing about gas hydrates, along with Edith Allison of DOE and Barbara Moore of NOAA. Senator Burns was seeking information that would help him frame his ideas about Energy policy and alternatives to foreign oil. USGS independently arranged for the same briefing to be given later in the day to the House Subcommittee on Energy and Mineral Resources. Both briefings were designed as an overview of hydrates (Hutchinson), an overview of federal cooperation in hydrate research (Allison) and frontiers of biological and chemical research (Moore). Each briefing lasted close to 90 minutes and was well received. (*See Attachment 3*).

(9) ***Conference Participation***

- *6 January, 2003*: GHASTLI database meeting, Woods Hole, discussed and reviewed existing database.
- *22-25 January, 2003*: Mallik 3L-5L Workshop, Whistler, BC, Canada (Winters and Lorenson)
- *28 January, 2003*: National Petroleum Council, Supply Team – Technology Subgroup, Gas Hydrates Workshop, Houston, TX (Hutchinson)
- *5-7 February, 2003*: ODP/DOE Pressure Coring Meeting, College Station, TX (Winters)
- *19 February, 2003*: Gas Hydrates JIP, Site Selection Progress Meeting, Houston, TX (Paull, Hart, Hutchinson)
- *4-5 April, 2003:* CODATA hydrate meeting, Paris, France (Winters)
- *7-11 April, 2003*: EGS-AGU-EUG Spring Meeting, Nice, France (Winters)
- *15 April, 2003,* Gas Hydrates JIP, Sea Floor Team Progress Meeting, Houston, TX (Hutchinson, Hart)
- *11-14 May, 2003*: AAPG Annual Meeting, Salt Lake City, UT (Winters, Lorenson)
- *25-27 May, 2003*: Legal and Scientific Aspects of Continental Shelf Limits, Reykjavik, Iceland (Hutchinson)
- *17-18 June, 2003*: MMS Brainstorming Session on Conducting a Hydrates Resource Assessment, Herndon, VA (Hutchinson)

(10) Related Activities:

- *6 January, 2003:* GHASTLI database meeting, Woods Hole, to discuss and review existing database structure and functionality.

- *16 January, 2003:* Briefing, 10:00 a.m. Staffers to Senator Conrad Burns, Dirkson Senate Building; Briefing, 1:00 p.m. House Subcommittee on Energy and Mineral Resources (Longworth House Office Building) (Briefing done jointly by Hutchinson, Allison, Moore, and USGS and NOAA liaisons).
- *31 January, 2003:* Winters visited Schlumberger, Houston to give a presentation of USGS field and lab programs.
- *31 January, 2003:* Winters visited Westport Technology Center International, Houston, TX, to have a tour of their gas hydrate facilities and to deliver reviewed copy of DOE-funded Gas Hydrate Coring and Preservation manual.
- *31 January, 2003:* Winters visited Bill Bryant (TAMU, College Station, TX) to discuss physical property measurements from the Gulf of Mexico cruise.
- *8 February, 2003:* Visit to the Woods Hole GHASTLI lab by Dr. Pushpendra Kumar, Superintending Chemist, Oil and Natural Gas Corporation, Ltd., India.
- *February, 2003:* Visit to the Menlo Park Petrophysics Laboratory by Dr. Pushpendra Kumar (Oil and Natural Gas Corporation, Ltd., India).
- *21 February, 2003:* Winters, Lorenson, and Paull present results from DOE-funded Marion Dufresne cruise to DOE in Morgantown, WV.
- *15 March, 2003:* Visit to GHASTLI lab and WHFC by Conn.-based Institute for Scientific Instruction and Study.
- *16 April, 2003:* USGS Visit to MMS to discuss regulatory and permitting issues associated with the 1-14 May seismics cruise in the Gulf of Mexico (Hutchinson, Hart).
- *23 May, 2003:* Visit to Woods Hole Field Center by Carolyn Ruppel to discuss May cruise results and August cruise planning with D. Hutchinson.
- *2 June, 2003:* Visit to Woods Hole Field Center by Carolyn Ruppel to discuss May cruise results and August cruise planning with D. Hutchinson.

(11a) Publications This Quarter - Papers

Chakoumakos, B.C., Rawn, C.J., Rondinone, A.H., Stern, L.A., Circone, S., Kirby, S.H., Ishii, Y., Jones, C.Y., Toby, B.H., and Dender, D.C., Termperature dependence of polyhedral cage bolumes in clathrate hydrates, *Can. Journ. Phys*, vol. 81 (*1-2*), p. 183-189, 2003.

Circone, S., Stern, L.A., Kirby, S.H., Durham, W.B., Chakoumakos, B.C., Rawn, C.J., Rondinone, A.J., and Ishii, Y., CO_2 hydrate: synthesis, composition, dissociation behavior, and a comparison to structure I CH_4 hydrate. *J. Phys, Chemistry B.*, accepted, 2003.

Durham, W. B., Kirby, S. H., Stern, L. A., and Zhang, W., 2003, The strength and rheology of methane clathrate hydrate, *J. Geophys. Res.,* vol. 108 (*B4*), p.2182-2193.

Durham, W. B., Stern, L.A., and Kirby, S. H., 2003, Ductile flow of methane hydrate, *Can. Journ. Phys*, vol. 81 (*1-2*).

Helgerud, M.B., Waite, W.F., Kirby, S.H., and Nur, A., 2003, Measured temperature and pressure dependence of Vp and Vs in compacted, polycrystalline sI methane and sII methane-ethane hydrate. *Can. Journ. Phys*, vol. 81 (1-2), pp. 47-53.

Helgerud, M.B., Waite, W.F., Kirby, S.H., and Nur, A., 2003, Measured temperature and pressure dependence of Vp and Vs in compacted, polycrystalline ice Ih,. *Can. Journ. Phys.*, vol. 81 (1-2), pp. 81-87.

Rawn, C.J., Rondinone, A.J., Chakoumakos, B.C., Circone, S., Stern, L.A., Kirby, S.H., and Ishii, Y., 2003, Neutron powder diffraction studies as a function of temperature of structure II hydrate formed from propane, *Can. Journ. Phys*, vol. 81 (*1-2*).

Rehder, G., Kirby, S.H., Durham, W.B., Brewer, P., Stern. L.A., Peltzer, E.T., and Pinkston, J.P., Submitted, Dissolution rates of pure methane hydrate and carbon dioxide hydrate in undersaturated seawater at 1000 m depth, *Geochem Cosmochim Acta.*

Stern, L. A., and Kirby, S.H., Grain and pore structure imaging of gas hydrate from core MD02-2569 (West Mississippi Site, Gulf of Mexico): a first look by SEM. In: Initial Report on Gas Hydrate and Paleoclimate Results from the RSV Marion-Dufresne Cruise to the Gulf of Mexico July 2-18, 2003. USGS/ Digital Data Series publication. (Submitted March 2003)

Stern, L.A., Circone, S., Kirby, S.H., and Durham, W.B., Temperature, pressure, and compositional effects on anomalous or "self" preservation of gas hydrates. *Can. Journ. Phys*, vol. 81 (*1-2*), p. 271-283, 2003.

(11a) Publications This Quarter - Abstracts/Presentations
(see attachment 4 for selected copies of Abstracts)

Collett, T.S., Lorenson, T.D., 2003, The Eileen-Tarn Gas Hydrate Petroleum System, Northern Alaska: AAPG Annual Meeting Salt Lake City, Utah 1p. Director's Approval 9/02.

Durham, W.B., Stern, L.A., and Kirby, S.H., The rheology of clathrate hydrates and its relationship to planetary ice. SMEC (Study of Matter under Extreme Conditions) conference, Miami, March 2003. (Invited talk)

Lorenson, T., Dougherty, J.A., and Flocks, J.G., 2003, Hydrocarbon Gases From Giant Piston Cores In The Northern Gulf Of Mexico: From Seafloor Vents To Minibasins: EGS/AGU/EGU Joint Assembly, Nice, France. 4/03. Director's Approval 1/03.

Lorenson, T., Winters, W., Paull, C., and Ussler, W. III., 2003, Gas Hydrate Occurrence in the Northern Gulf of Mexico Studied with Giant Piston Cores: From Seafloor Vents to Minibasins: EGS/AGU/EGU Joint Assembly, Nice, France. 4/03. Director's Approval 1/03.

Lorenson, T., Winters, W., Paull, C., Ussler, W. III, and the PAGE 127 Shipboard Scientific Party, 2003, Gas hydrate occurrence in the Gulf of Mexico studied with giant piston cores: from seafloor vents to minibasins; To be presented at the EGS-AGU-EUG Joint Assembly, Nice, France, April 7-11

Lorenson, T.D., Winters, W., Paull, C., and Ussler, W. III., and the PAGE 127 Shipboard Scientific Party, 2003, Gas Hydrate in the Northern Gulf of Mexico: New Insights Learned from Giant Piston Coring: AAPG Annual Meeting Salt Lake City, Utah 1p. Director's Approval 9/02.

Paull, C., Ussler, W. III, Winters, W., Lorenson, T., and the PAGE 127 Scientific Party, 2003, Constraints on the distribution of gas hydrates in the Gulf of Mexico; To be presented at the EGS-AGU-EUG Joint Assembly, Nice, France, April 7-11

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Soh-joung Yoon, Keith W. Jones, Huan Feng, William J. Winters, and Devinder Mahajan, 2003, Methane Hydrate Studies: Delineating Properties of Sediments by Computed Microtomography (CMT); Presented at at AICHE Spring National Symposium on Gas Hydrates, New Orleans, March 30-April 3

Waite, W.F., Winters, W.J., and Mason, D.H., 2003, Hydrate formation and compressional wave development in partially saturated Ottawa sand; To be presented at the EGS-AGU-EUG Joint Assembly, Nice, France, April 7-11

William J. Winters, Scott R. Dallimore, Timothy S. Collett, Alan E. Taylor, Barbara Medioli, Ryo Matsumoto, John T. Katsube, J. Frederick Wright, F. Mark Nixon, Adrienne Ethier, and Takashi Uchida' 2003, Physical Properties of Sediments from the 2002 Mallik 5L-38 Gas Hydrate Production Research Well, NWT, Canada; Presented at Mallik 3L-5L workshop, Whistler, BC, Canada, Jan 22-25

William J. Winters, William F. Waite, David H. Mason, Ivana Novosel, Olga M. Boldina, Thomas D. Lorenson, and Charles K. Paull, 2003, Field and Laboratory Studies of Sediment Containing Natural and Synthetic Gas Hydrate; To be presented at Symposium on Gas Hydrate - A Potential New Energy Source for the New Millennium, Qingdao, China, July 14-16

Winters, W.J., Waite, W.F., Mason, D.H., Lorenson, T.L., Paull, C.K., Novosel, I., Boldina, O.M., Dallimore, S.R., Collett, T.S., and the PAGE 127 Shipboard Scientific Party; To be presented at the EGS-AGU-EUG Joint Assembly, Nice, France, April 7-11

ATTACHMENT 1

PRELIMINARY DRAFT

Cruise Report for G1-03-GM

USGS Gas Hydrates Cruise,

R/V Gyre, 1-14 May, 2003, Northern Gulf of Mexico

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and

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This report is preliminary. It is NOT a citable reference and is being distributed for information purposes only. When all appendices are completed, it will be submitted as a USGS Open-File Report.

Introduction – Gas Hydrates in the Gulf of Mexico

Gas hydrates are well known for their capacity to change the physical properties of near surface sediments and have been linked to massive slope failures on continental margins (refs). As drilling in the Gulf of Mexico has progressed from shallow-water shelf depths (< 200 m) to deep-water slope depths (> 1,000 m), wells now penetrate the gas hydrate stability zone. Because drilling can change the physical conditions around the drill hole (for example, by allowing warm fluids from depth to circulate shallow in the hole), potentially causing hydrate to dissociate (i.e., melt), many researchers and engineers anticipate that drilling through hydrate may pose a hazard to the stability of the well, the platform anchors, tethers, or even entire platforms (Hovland and Gudmestad, 2001). In order to understand these consequences to drilling, it is imperative to understand the physical and chemical conditions and the geological environment in which these hydrates exist and to be able to estimate the distribution and concentration of gas hydrate deposits. In May 2003, USGS conducted a 14-day cruise aboard R/V Gyre to collect high-resolution seismic reflection data and develop the geologic framework around two potential deep-water sites anticipated to be drilled in spring, 2004, to study gas hydrates in the Gulf of Mexico.

The Gyre cruise (USGS cruise ID: G1-03-GM) is one part of a much larger program of hydrate research in the Gulf of Mexico. Specifically, the cruise is coordinated with a Joint Industry Program (JIP) funded by the Department of Energy (DOE) to assess the hazard that hydrates pose to deep-water drilling. The two primary study areas for the cruise, lease blocks Keathley Canyon 195 and Atwater Valley 14 (Fig. 1), were selected from 6 sites that the JIP originally considered for drilling. The cruise is coordinated with additional site-survey work being done in August, 2003, using near-bottom instrumentation (the Deep-Towed Acoustic/Geophysical System (DTAGS) multichannel seismic instrument from the Naval Research Lab, heat flow measurements from Georgia Tech, and electrical resistivity measurements from the Woods Hole Oceanographic Institution). Selected lines from the USGS Gyre cruise will be re-occupied by these specialized instruments to further characterize the geology and hydrate character of the potential drill sites. This work also builds on a strong foundation of hydrate research in the Gulf that has been built by numerous academic research groups (see Sassen and other, 2001, and Roberts, 2001, and references therein).

This cruise report gives an operational summary of the Gyre 2003 cruise. The information covered includes descriptions of the instrumentation, on-board operations, tabulated statistics, and textual and map summaries of the data. Examples of the data collected are given in short summaries of each site survey. Scientific results and interpretations will be presented elsewhere.

Acknowledgements

Support for the Gyre 2003 cruise was provided jointly by USGS and DOE. We gratefully acknowledge the support and encouragement from the JIP and especially from Emrys Jones of Chevron-Texaco, Mike Smith of MMS, and Fred Snyder, Lecia Miller, and Nader Dutta of WesternGeco who provided invaluable access to proprietary data that facilitated cruise planning. Discussions with Warren Wood, Carolyn Ruppel, Charlie Paull, Dave Twichell, Alan Cooper,

Will Sager, and numerous other researchers with knowledge of the geology and geophysics of the Gulf helped focus our efforts in developing a cruise plan. Finally, we are indebted to the able ship handling and concerted efforts of Captain Dana Dyer and the crew of the Gyre, without whose diligence and efficiency this cruise could have happened.

Geologic Setting

The Gulf of Mexico has been classified as a small ocean basin (Menard, 1967), and the northern Gulf of Mexico consists of a wide shelf, shelf break, slope and rise morphology found on passive continental margins. The present physiography of the slope is dominated by salt tectonics, in which hummocky bathymetry is dominated by irregularly shaped salt withdrawal basins and the intervening structural highs that are often underlain by diapers (Bouma and Roberts, 1990; Winker and Booth, 2000). Terrigenous siliclastic deposition, dominated in the Pleistocene and Holocene by the Mississippi River, characterizes most of the basins and intra-basin settings (Winker and Booth, 2000). During its evolution, the Mississippi River depositional path variously followed the Alaminos, Keathley, and Mississippi Canyon pathways (Bryant and others, 1990). Keathley Canyon 195 is on the mid-slope near the junction of four mini-basins at about 1,300 m water depth; Atwater Valley 14, also in about 1,300 m water, is in a very different setting on the floor of the Mississippi Canyon (Fig. 1).

The Gulf of Mexico presents a unique setting for gas hydrates when compared to most other continental margins of the world. Both oil and gas are actively produced in the Gulf, and abundant leakage (i.e., venting) provides a thermogenic source of gas to the shallow section for forming hydrates (Roberts, 2001), especially much rarer forms of structure II hydrate (Sassen and others, 2001). Hydrates in the northern Gulf have also been characterized primarily from studies of hydrate mounds on the sea floor (Roberts and others, 1992; Roberts, 2001) rather than the more commonly known seismic indicator of hydrates, the Bottom Simulating Reflection (BSR). The lack of a BSR is puzzling, given the abundant gas in the Gulf, although observations of BSRs in Walker Ridge (McConnel and Kendall, 2003) and elsewhere in the Gulf are now beginning to be reported. The few BSR's that have been observed in the northern Gulf are weaker and less recognizable when compared with the BSRs that characterize well-known gas hydrate regions such as the Blake Ridge (Dillon and Paull, 1983), Hydrate Ridge (Trehu and others, 1999), and Nankai trough (Arato and others, 1996).

The Gulf of Mexico is also unique because of the extreme salt tectonics that occur. This widespread salt may be related to the paucity of BSRs in two fundamental ways: salt is an inhibitor to hydrate formation, so that the presence of abundant shallow salt on the continental slope may act to limit hydrate formation (Paull and others, 2003). The salt tectonics and related raluting and fluid/gas venting may also distort the base of the gas hydrate stability zone, limiting the subjacent accumulation of laterally continuous zones of free gas necessary for a recognizable BSR (Cooper and Hart, 2003). The complexity of the geologic setting together with the abundant hydrocarbon development are factors which set the Gulf apart from other hydrate settings.

Cruise Objectives

The five primary objectives of the Gyre cruise were:

Characterize the shallow seismic stratigraphic framework of the two site survey areas

This objective addresses understanding the geologic framework of each site, i.e. to understand the stratigraphic and structural relations and how they might affect or alter hydrate occurrence. Success in meeting this objective requires collecting seismic reflection data sufficient to image the subbottom environment in which gas hydrate might occur and to relate local features to the broader understanding of the geology of the basins and structural highs in the Gulf of Mexico.

Acquire data to map the distribution of acoustic indicators of gas hydrate

Several seismic indicators exist for identifying hydrate in the subsurface: the bottom simulating reflection (BSR), zones of amplitude blanking, and zones of enhanced reflections that may indicate the presence of free-gas trapped beneath the hydrate stability zone. Understanding the spatial distribution of these indicators can help determine the likely presence of hydrate in the sediments, as well as the places where hydrate may be most concentrated (and therefore a target for a drilling experiment). Good spatial coverage of high-quality, high-resolution data are needed to meet this objective.

Tie to pre-existing public-domain seismic data and available well information

Part of interpreting the geologic framework of the sites involves integrating the cruise data with existing seismic data and their interpretations as well as calibrating the seismic data with existing sample information, preferably well data. MMS provided the nearest well ties for the two sites. Ties to public-domain seismic data were determined from pre-existing USGS data sets and knowledge of the deep-seismic reflection LSU-B line.

Identify transects to reoccupy with near-bottom instrumentation

Geophysical characterization of the sites for potential drilling requires integrating the seismic reflection data from this cruise with near-bottom instrumentation measurements that will be collected in August, 2003 (DTAGS, heat flow, electrical resistivity, and possible shallow coring). Because the instruments for making near-bottom measurements are not regional mapping tools, identifying the best locations to collect these specialized data needs to be carefully considered. Therefore, the data from this Gyre cruise are particularly important in identifying the best sites at which to collect the more expensive and more specialized near-bottom data.

Contribute to selecting potential targets for gas hydrate drilling

Integrating the information from objectives A through D should lead to narrowing the geographic boundaries for hydrate drilling targets, e.g., identify key locations in target lease block areas. While the purpose of this cruise is not to explicitly pick the drill sites, the seismic data are expected to contribute to prioritizing sites for drilling. Data will be also be used to formulate models of hydrate-free and hydrate-bearing sediments. These models can be directly tested the JIP drilling. The seismic data collected during G1-03-GM are near-zero offset and therefore do not yield seismic velocities that can be used to convert reflection times to reflector depths. However, the higher vertical resolution of the data will enable a more detailed interpretation of the gas hydrate stability zone than is possible with most standard industry data.

Cruise Strategy

The two study areas posed different imaging challenges. Keathley Canyon 195 had evidence for a low-amplitude BSR in proprietary industry data, and therefore offered the opportunity to identify a mappable horizon and relate it to the surrounding geology. Atwater Valley 14, again from proprietary industry data, contained three possible mound/vent sites that were targets for potential hydrate formation, but no obvious BSR. Therefore, the strategy for mapping each survey area was different: For Keathley Canyon, the objective was to acquire a grid of data and define the regional extent of a possible BSR. Additional detailed (100 m spacing) lines were added to look at specifics of the BSR and at a possible mound/vent within the study area. For the Atwater Valley study area, the objective was multiple crossings over the three mound/vent sites from different azimuths and with close (100 m) line spacings.

The chronology of the cruise, showing the time spent in each survey area and doing the ties to other well and seismic information are given in Table 1.

Table 1: Cruise Chronology

Julian Day[1]	Work Area	Seismic System	Strategy
121-122	Transit	None	Depart Galveston and transit to Keathley Canyon 195 Area
123	Keathley Canyon	All	Test single channel seismics, multichannel seismics and optimize acquisition parameters
123-128	Keathley Canyon	13/13 in^3 GI Gun Knudsen	Grid lines, detailed surveys, and well tie
128-129	Keathley Canyon /Garden Banks	24/24 in^3 GI Gun Knudsen	Profile along LSU-B and tie to 1999 USGS data
129-130	Transit	None	Transit to Atwater Valley 14 area

130-133	Atwater Valley	13/13 in^3 GI Gun Knudsen	Detailed grids in Atwater Valley and tie to Mississippi Canyon 802 Marion Dufresne (2002) core site
133-134	Transit	None	Return to Galveston

[1] G1-03-GM lasted for 14 days from 1-14 May, 2003. Julian Day 121 corresponds to 1 May.

Because of the large number of short lines anticipated on the cruise, a naming convention was used in which the line number always incremented by one, but the alpha-numeric leader would change depending on the region being surveyed (KC = Keathley Canyon, GB = Garden Banks, AV = Atwater Valley, MC = Mississippi Canyon). Hence line KC60 (for Keathley Canyon 60) was followed sequentially by line GB61 (for Garden Banks 61). The test lines at the start of the cruise were an exception. For the test multichannel water gun line, the multichannel data were labeled Test2. The test GI gun line was initially called test4, but renamed to KC1 when it was decided to use the GI gun as the primary source for the survey. The Knudsen bathymetry files for KC1 were labeled L1.

Instrumentation

1. Navigation

Primary navigation for G1-03-GM was by Differential Global Positioning System (DGPS), from a Communications System, Inc. (CSI) DGPS Max receiver that utilized wide area augmentation system (WAAS) corrections. YoNav software (developed by the USGS, version 3.14) logged the DGPS positions together with the gyro-compass heading and waterdepth, provided map display of position, distributed the navigation to other acquisition and display systems, and output a shot trigger for the seismic source. A separate computer off the YoNav server provided a graphical monitor to assist bridge steering along trackoines. Features included in YoNav are cross-track distance off line, distance to go, distance along line, speed, and heading. The DGPS antenna was installed in an open area on the bridge deck and was measured to be a horizontal distance of 26 m from the stern of the vessel. Mike Boyle and Larry Kooker were primary YoNav and DGPS technicians.
Photographs of the navigation system are shown in Appendix 6.

2. Multichannel Seismics

The components for the multichannel seismic system consisted of the source, the receiving array, and the digitizing and recording PCs.

Two sources were used: a Seismic Systems, Inc. 15 in^3 water gun (operated at 2000 psi pressure), and a Seismic Systems, Inc. Generator-Injector (GI) gun (operated at 3000 psi pressure). A Bauer, 4-cylinder, 50-scfm diesel compressor provided the high-pressure air for the guns. The GI gun is a dual-chamber air gun designed to minimize the bublle pulse. The "injector" chamber of the GI gun is timed to discharge a short time (typically 20-30 msec) after the "generator" chamber so as to suppress the bubble pulse and create an optimal signal. It was used with chamber inserts for a 13/13-in^3 configuration (i.e., 13 in^3 generator chamber, 13 in^3 injector chamber) for most of the cruise and was fired at 20-m intervals. The water gun was used for a test line at the beginning of the cruise and could be fired at 10-m shot intervals because it has only a single chamber. The GI gun with a 24/24 in^3 chamber was used for 4 lines in the middle of the cruise, but the larger source size could only be fired at longer space intervals (30 m). The larger source size was judged not to compensate for the lower fold stacking in the processing, and therefore the smaller chamber was reinstalled. The GI gun was towed off the starboard stern 24 m aft of the stern and 50 m aft of the GPS antenna. It was suspended by a towing harness 1 m beneath the surface by a large inflatable buoy. Firing was by distance (10-m shots for the water gun, 20-m shots for the 13/13 GI gun; 30-m shots for the 24/24 GI gun). The firing pulse generated by YoNav went to a SEAMAP Seislink seismic interface box, then into a Sureshot computer system (version 3.06) which enabled optimizing firing between the generator and injector chambers. Hal Williams and Walt Olson were responsible for operation of the guns and compressor.

The receiving array consisted of an Innovative Transducers, Inc. solid-core 24-channel, 240-m array. Each channel had 3 "thin-film" cylindrical hydrophones of polyvinylidene fluoride (PVDF) plastic. Channel spacing was 10-m. A lead in section 24-m long was used; a polyform float at the end of polypropylene line formed the tail buoy. The streamer was weighted to tow about 1-m beneath the surface. At the beginning of the cruise, channels 16 and 18 were known to be dead. During testing, channel 24, which was at first intermittent, then also ceased working. In bad weather conditions, channels 23 was often too noisy to be used. The analog signals sensed by the streamer were brought into the StrataView acquisition system in the lab via a deck leader.

A Geometrics StrataView unit served as the multichannel acquisition system. Location information from YoNav together with the 24-channel data were recorded in SEG-D format on 4 gigabyte Sony DDS 4-mm tape cartridges. Data were digitized and recorded at a sample interval of 0.5 ms. Record lengths were 4 s with a 1 s deep-water delay (i.e., 1-5 s record window) except for lines where the sea floor was shallower than 1 s. The StrataView consisted of two computers, one for data digitizing, the other with a graphical user interface for quality control and recording parameter selection. The at-sea display to monitor data quality consisted of multiple windows showing in real-time the near trace (generally the second nearest channel), the time between triggers (usually about 10 s for the small GI-gun configuration), a shot gather enlarged to show the water bottom return, a display of noise on all 24 traces, and various header information. The near trace monitor was printed at the end of every line showing ffid number and gain settings. These near trace plots provided an initial glimpse at the seismic stratigraphy along each line. The ffid number was generally kept sequential on all lines on one tape, and reset to 1 at the beginning of a new line on a new tape. Larry Kooker and Mike Boyle had primary responsibility for the multichannel acquisition system.
Photographs of the multichannel seismic instrumentation are shown in Appendix 6.

3. Bathymetry

The hull mounted 3.5 kHz transducer mounted beneath the water line on the bow of the Gyre provided the signal for the bathymetric record. This was triggered by a Knudsen 320B/R fathometer system with an external display showing gated windows (generally in 200-m increments). Recording was done directly to shared disk using the naming convention of "*Line Number*"_LF_000.sgy, where "*Line Number*" was manually entered at the start of every line. The "000" designator augmented when multiple files were written for each line. A new file automatically started each time a setting on the Knudsen was changed (e.g., to change the depth display range). Hence lines in changing water depth often had many files. The firing interval was every 2 s (approximately 4 m assuming 4 kt vessel speed). The sampling interval was 40 microseconds (25 kHz), and only the gated window in the monitor display was recorded.

Along lines when sea conditions were calm and the water-bottom return showed sufficient signal-to-noise ration to enable the Knudsen's automatic water bottom picking algorithm to work, a digital depth reading was sent to the YoNav navigation recording computer to be logged with position in the navigation files. During these periods of relatively calm seas, the 3.5 kHz chirp record showed up to 80 m of sub-bottom imaging. Tom O'Brien, Mike Boyle, and Larry Kooker set up and tuned the Knudsen bathymetry system.
Photographs of the Knudsen bathymetric system are shown in Appendix 6.

4. Single Channel Seismics

Two single channel seismic systems were brought on the cruise, with the intention of using the one that provided the highest quality data. These were the EdgeTech Full Spectrum Sub-bottom (Chirp) Profiler and the Huntec Deep Tow System (DTS). Neither of these single channel systems were used during the cruise, after testing the first day in calm seas showed that neither system was achieving significant subbottom penetration in the 1300-m water depths of the test line. If these systems had been used, separate digital acquisition would have occurred on a Delph Seismic acquisition system. Graham Standen served as the primary technician for the Huntec DTS.
Photographs of the EdgeTech and Huntec systems are shown in Appendix 6.

5. Local Area Network (LAN)

In order to facilitate sharing of data between computers and disks, a local area network was set up on the Gyre. This consisted of a 24-port Netgear network switch in the main lab, into which the various main-lab acquisition systems and computers connected. This switch also provided two gigabit Ethernet interfaces to additional network switches in the seismic processing lab and the GIS lab, both one deck above the main lab. The various computers in those labs connected into the network via those switches. Connectivity was via 10/100 megabit interfaces.

The backbone of data storage was supplied on two snap servers (each providing 320 gigabytes of disk space). One server was dedicated storage for the multichannel seismic data. The other served for the storage of the Knudsen data and other cruise needs (e.g., navigation files, cruise maps, etc).
A photograph of the LAN system is shown in Appendix 6.

Data Processing

1. Seismic Processing Lab

The seismic processing lab, located above the main lab one deck up, contained two Unix-basedseismic processing computers, two seismic processing software packages (ProMAX 2D and FOCUS), and a DVD writer. Processing was split between the two systems. The bulk of the geometry merging was done on ProMAX, and the bulk of data processing on FOCUS. After SEG-D input, all data were stored on the dedicated Snap server until archived to DVD. A 12 inch OYO Geospace thermal plotter was used to plot preliminary and final sections at a scale of 5 inches/second. The processing sequence follows:

Using Promax:

SEG-D demultiplexed format input

(Multiple lines per tape; shot coordinates read from SEG-D headers)

SEG-Y output of raw shot records

(One line per file; 0.5 ms sample interval; Archived on DVD)

Geometry input

(CDP and Receiver UTM coordinates written into trace headers)

CDP sort

SEG-Y output of CDP sorted records

(1.0 ms sample interval; Archived on DVD)

Using FOCUS

Edit of noise spikes and noisy channels
Whole trace amplitude balance
Deep-water delay correction
FK filter
Spiking deconvolution
NMO correction
Stack
Spherical divergence correction
60-360 Hz bandpass filter
SEG-Y output of stacked profiles

(1.0 ms sample interval; Archived on DVD)

Several conventions were followed in the processing: original ffid's were preserved, but all shots were renumbered starting at 1 at the beginning of every line. All geometry was calculated in absolute coordinates, i.e., UTM positions calculated from the latitude/longitude positions supplied by YoNav. Keathley Canyon was in UTM zone 15; The Atwater Valley region was in UTM zone 16. The initial geometry definition involved extracting the position information from the headers in the SEG-D field records, calculating a corrected UTM x and y position for the actual shot location (using a combination of MATLAB and ArcGIS), then using ProMAX to do full geometry to accurately locate all CDP and receiver locations. The SEG-Y data with geometry were read back into FOCUS for processing through stack. Although data were recorded to 5 s, stacks were only done to 4.5 s. Stacking was not sensitive to velocities because of the short streamer length (240 m) and large water depths (1300 m). A generic velocity was used that consisted of 1500 m/s rms to the sea floor, then increasing to 2000 m/s at 3 s twtt and 2500 m/s at 4.5 s twtt. For the multichannel data with the 13/13 GI gun, data generally stacked to 6 fold at 5-m cdp spacing. Final navigation was extracted from the cdp x and y locations (SEG-Y trace header locations 181-184 and 185-188) and converted back to latitude and longitude values. Ray Sliter and Erika Geresi ran the seismic processing lab. Photographs of the seismic processing lab are shown in Appendix 6.

2. GIS lab

A separate GIS lab, located just forward of the Seismic Processing Lab, provided GIS support for the cruise. A desk-top computer running ARCGIS and ARCView maintained all the master files and master calculations for cruise data. This computer was used to define all track lines, perform mid cruise planning adjustments, and calculate corrected shot positions. Initial (i.e., planned) track lines were exported to YoNav in both the main lab and the bridge for underway navigation. Metadata for all new shape files and tabulated information was also created and archived here. Seth Ackerman and Jen Dougherty oversaw the GIS lab.

Photographs of the GIS Lab are shown in Appendix 6.

Data Handling and Archive

Data from this cruise consist of both field and processed records: field data for the navigation, multichannel seismics, and Knudsen; processed data for the multichannel raw shot records, CDP sorted data, and stacked sections. The only data recorded directly to tapes during acquisition were the multichannel field records. All other data was recorded directly onto disk and later written to either CD or DVD for archive. Tables of the tapes, CD's and DVD's created during this cruise are given in Appendix 2.

Marine Mammal Mitigation

With new regulations protecting marine mammals and endangered species, cruise G1-03-GM prepared for marine mammal mitigation by submitting a request for Incidental Harassment Authorization (IHA) to NOAA/National Marine Fisheries Service (NMFS). This request outlined proposed source sizes, decibel levels, likelihood of incidental "take," and proposed mitigation procedures to avoid harassment of marine mammals within the survey areas. The proposed mitigation procedures included contracting observers to watch for marine mammals during daylight hours, monitoring work areas for 30 minutes prior to start up of seismic sources, not beginning new seismic operations or resuming seismic operations after a shutdown during the night, and establishing impact or safety zones for each seismic source to be used. These safety zones were defined by the radius to the 180 dB or 160 dB isopleth and seismic sources would be turned off if marine mammals enter the zone. Table 2 summarizes the safety zones proposed.

Table 2: Proposed Safety Zones for Acoustic Sources used on G1-03-GM

Seismic Source	Sound Presure Level (SPL) Re 1 microPascal-1 m rms	160 dB radius	180 dB radius
Huntec boomer	205 dB	175 m	17 m
Edgetech 512I chirp	198 dB	75 m	8 m
15 in^3 water gun	204 dB	170 m	15 m
35/35 in^3 GI gun	208 dB	250 m	25 m
24/24 in^3 GI gun*	208 dB*	250 m	25 m
13/13 in^3 GI gun*	204 dB*	170 m	15 m

*The safety zones and SPL values for the GI gun in 24/24 in^3 and 13/13 in^3 configurations were not proposed at the time of request for authorization, but were determined later by comparison with similar seismic sources.

Copies of the NOAA/NMFS permit, the cover letter to NOAA, the request for IHA, the request to MMS, and the final marine mammal report are given in Appendix 3. Mary Jo Barkaszi and Richard Holt of ECOES were the contract marine mammal observers aboard the Gyre.

Operational Summary by Area

Keathley Canyon Survey Area

A total of 63 lines were collected in the Keathley Canyon site, excluding the three lines during which the seismic gear was tested and tuned. Lines 1-59 totalled 600 km. Line 60, which followed line LSU-B northwards out of the Keathley Canyon area to tie with the 1999 USGS multichannel data was 85 km long. Another 62 km of profiles were acquired on lines GB61-GB63 at the north end of the survey area. Line locations in the Keathley Canyon area were designed to give an overview of the region with 1-km spacings on an orthogonal east-west/north-south grid and shorter closely spaced (either 500-m or 100-m) transects over specific features of interest. The trackline map (Fig 2) shows the dense line coverage. Lines outside of the grid connected to three additional data sets: the closest well in the area for a line tie, a deep seismic reflection profile (LSU-B) that provides a regional geological overview of the continental margin (Suh, 1988), and USGS 1999 multichannel data in the Green Canyon region (Hart and others, 2002). The last two ties, (i.e, lines KC60 and GB61-GB63, along the LSU line, and to the 1999 data) were shot with the larger (24/24) GI gun configuration.

At the start of the survey, an east-west test line location was chosen to tune up the seismic systems. A possible Bottom Simulating Reflection (BSR) is observed on proprietary data along the test line location, and therefore offered a target for testing the equipment. The single channel seismics were tested first. The Huntec was towed at approximately 180-m deep, but after 4 hours had produced only minimal subbottom imaging with very low signal-to-noise ration. Subsequent tests with the Edgetech Chirp system over 3 hours also failed to produce consistent bottom or subbottom data. The conclusion from these tests was that neither of these systems were appropriate for the mid-slope water depths (~ 1300 m) at the Keathley Canyon 195 site.

The next phase of the testing was to compare sources for the multichannel data. The 15-in^3 water gun (used in the 1999 multichannel survey in Green Canyon, Hart and others, 2002) was tried first, fired at 2000 psi every 10 m (Fig. 3). The line was then reshot with the 13/13 in^3 GI gun, fired at 3000 psi every 20 m (Fig. 4). A comparison of the near trace gathers for each source showed that the GI gun had improved signal-to-noise characteristics, deeper penetration, and better reflection quality at almost all subbottom depths. The conclusion from these tests was that the better source traits of the GI gun would more than offset the decrease in fold caused by the larger shot spacing (6 fold for the 20-m GI gun shots versus 12 fold for the 10-m water gun shots). A comparison of the initial stacks of the water gun and GI gun data (Figs. 3 and 4) are consistent with this conclusion.

Near the end of the Keathley Canyon survey a second test of multichannel sources was run comparing the 13/13 in^3 GI gun configuration with the 24/24 in^3 GI gun chambers (Fig. 5). This test was to assess the trade-off between a larger chamber source (24 in^3) but fewer shots (30-m shot spacing and 4-fold stacking). Subsequent processing revealed little difference between the 13-in^3 and 24-in^3 records, and the smaller 13-in^3 chambers were reinstalled during the transit between the Keathley Canyon and Atwater Valley sites.

The multichannel seismic data from the Keathley Canyon area were generally of excellent quality, with penetration of the seismic signal beneath the sea floor in the basins in excess of 1 s two-way travel time (twtt) and penetration beneath the sea floor on the highs adjacent to the basins about .5 - .8 s twtt. Line KC9 is an excellent example of data quality for the Keathley Canyon lines (Fig. 6). The record illustrates a rich pattern of unconformities, pinch-outs, on-laps, and faults between the basin center and structural high at the edge of the basin. In addition, the record shows abundant diffractions at the sea floor and within the reflecting units, and numerous amplitude variations. A crosscutting event at CDP 2042 and 2.6 s may be a segment of a BSR.

Knudsen data quality in the Keathley Canyon area was weather dependent. For the first part of the survey, when weather was calm, subbottom reflections were strong and penetration of the signal beneath the subbottom was excellent, often greater than 40m and sometimes reaching as much as 80 m (Fig. 7). However, by line KC6, the swell was picking up with a strong southerly air flow (>20 kts), and the bathymetry signal deteriorated. By line KC9, and through the rest of the Keathley survey, the signal was weak and erratic on lines going with the seas, and essentially non-existent on lines into or cross-wise with the 6-10 foot seas.

Atwater Valley Survey Area

A total of 253 km of MCS data along 35 short lines was collected during the survey in the Atwater Valley 14 lease block (Fig. 8). Profiling here was designed around detailed north-south and east-west surveys (5 km long lines each 100 m apart) of each of the three vent/mound sites identified by the JIP as hydrate targets. A shorter grid of lines spaced more widely to give the geologic setting were rotated approximately 45^o from north-south to be more orthogonal to the seas created by the strong southeast winds at the start of the survey and to connect profiles between vents/mounds. The winds gradually died to zero during the three days of profiling so that the final lines shot (in the east-west orientation) were among the best for data quality.

Line AV97 (Fig. 9) shows an example of the stacked MCS data collected across the center of one of the three mound/vent sites. Data quality is excellent. Among the features visible on the record section are abundant sea-floor diffractions, discontinuous reflections, zones of very strong amplitudes, zones of wash outs, and possible pull-downs beneath the vent/mound sites. Seismic stratigraphy is complicated with many unconformable shallow reflections and multiple dipping reflections (on the east side of the section). The dipping reflections show good signal penetration to greater than 1 s twtt. The strength of these dipping reflections at these depths suggests that the absence of reflections at similar depths in other parts of the record (e.g., beneath the vent/mounds) is due to attenuation of the signal or the disruption of the sedimentary section.

Lines AV99, MC100 and MC101 connected the Atwater Valley lines up the axis of the Mississippi Canyon to two Marion Dufresne core sites collected by USGS in 2002 (sites 2569 and 2570, Lorenson and others, 2002). These lines also crossed the 1998 USGS MCS data around these core sites, providing a line tie.

Knudsen data quality in Atwater Valley, as in the Keathley Canyon region, was dependent on the weather. As the winds and seas moderated during the time spent at the Atwater site, the quality of the bathymetric record improved. In general, the bottom return was strong with few subbottom reflections, suggesting a harder, more reflective sea floor than in Keathley Canyon. The line collected northwestward along the axis of the Mississippi Canyon (AV99) crossed regions of varying sea floor returns, including many layered units within the subbottom, showing the variations in bottom type within the floor of the Canyon.

Success in Meeting Objectives

Cruise G1-03-GM, in collecting 1033 km of MCS data along 101 lines, has provided a large amount of new data for understanding hydrate occurrence in two regions of the north-central Gulf of Mexico. Together with the ties to previous surveys, core locations, and well data, this new data set offers new insights into the shallow geological processes within the hydrate stability zone. A quick review of the objectives of the survey shows that each of the primary objectives has been met with considerable success:

• Characterize the shallow seismic stratigraphic framework of the two site survey areas

The data acquired in both survey regions shows abundant reflections and reflection geometries that should enable both the structural and stratigraphic framework to be interpreted. The close line spacing and numerous line crossings will allow for an internally consistent interpretation to be traced through each area. Where reflections are not always continuous (e.g., around the mound/vent sites in Atwater Valley), the data should allow patterns of reflectivity to be mapped, providing another dimension to the interpretation. This objective is considered fully met.

• Acquire data to map the distribution of acoustic indicators of gas hydrate

The multichannel seismic data contain a rich variety of acoustic information about the sea floor and sub-sea floor environment. Preliminary assessment of the data shows that the right types of acoustic indicators of hydrate are present (e.g., cross cutting relations that might indicate a BSR, blanking zones, strong amplitudes indicative of gas, Figs 4, 6, and 8). A high-amplitude, continuous BSR was not obvious in the Keathley Canyon data, although shorter segments may have been imaged. The many diffractions on most of the data will need to be migrated to more accurately depict the reflection geometries. Without fully interpreting and mapping the acoustic indicators for hydrate, it is not possible to evaluate whether the objective of mapping them is reached. Mapping is a post-cruise exercise. This objective is considered to be successfully met.

• Tie to pre-existing public-domain seismic data and available well information

Each of the survey areas included ties to nearby pre-existing seismic, well, and core data. Hence this objective is considered to be successfully met. It remains a post-cruise task to interpret the ties and know whether the geologic framework can be integrated into this pre-existing framework.

• Identify transects to reoccupy with near-bottom instrumentation

Identifying transects to reoccupy will come from post cruise analysis that results in maps of features and sets the geologic framework. In achieving the three previous goals, there are excellent targets to consider, and it is expected that this objective will be fully achieved in the post cruise analysis phase of the project.

• Contribute to selecting potential targets for gas hydrate drilling

As with the previous objective, the seismic data collected on G1-03-GM need to be integrated with other data to know of their ultimate value in determining and prioritizing drilling targets. However, the data are an excellent start in building a high-resolution framework for the two potential drilling areas.

From an operational view, the cruise was also a success. Two notable accomplishments are firsts for at-sea MCS operations for USGS: (i) defining all the acquisition geometry in geographic (rather than relative distance) coordinates and merging this geometry into the SEG-Y data trace headers; and (ii) processing all MCS data with a complete and final processing sequence through stack. The importance of this is that all data were viewed in near real-time for quality control and all lines were ready for loading into an interpretation package and for distribution to project partners when the ship returned to the dock, rather than the usual 6-12 months post-cruise time frame for processing MCS data.

The only down time for the MCS system was 4 hours during which a safety valve on the compressor needed replacing. It was a disappointment that the single channel systems could not provide useful data in the water depths (1300 m) of the survey areas, but this was known as a possibility because of operating at the limits of their specifications. The weather and 6-10 foot seas in the middle of the cruise seriously degraded the quality of the Knudsen bathymetric system, but did not seriously degrade the MCS data. Weather is an unavoidable risk on any cruise, and the bathymetric data are not essential to interpreting the MCS data.

Recommendations for the Future

- Better weather!
- Single Channel Chirp or other high-resolution (>1000 Hz) seismic reflection system with the capability to provide useful subbottom data in 1,300 m water depths.
- Back-up 3.5 kHz system that could be used in rough weather (rather than the hull mounted transducer on the bow of the Gyre).
- 100 SCFM air compressor that could provide air capacity to fire the GI gun in a 13/13 mode at 10-m intervals.
- Longer multichannel receiver array with depth control system (A 600-m, 60-channel streamer could be deployed from a ship the size of the Gyre and combined with a 100-SCFM compressor, would allow 30-fold (vs 6-fold for this cruise) data acquisition).

Summary

Cruise G1-03-GM resulted in 1033 km of high-resolution multichannel seismic reflection data collected in two regions in the northern Gulf of Mexico. A total of 779 km of data were collected in the vicinity of Keathley Canyon lease block 195. Approximately 253 km were collected to the east in the Atwater Valley lease block 14 on the floor of the Mississippi Canyon. Multichannel data quality was generally excellent, with the GI gun configured with 13/13 in^3 chambers providing the best overall source for the cruise. All data were demultiplexed and processed through stack at sea, providing near real-time feed back on data coverage and results. A notable operational achievement was to define the geometry in geographic coordinates during the processing sequence.

Plots of the stacked data contain abundant reflections for interpreting the shallow stratigraphic and structural setting of each region. The data set contains excellent coverage and detail for understanding the geological framework and seismic characterization of the hydrate stability zone. The Keathley Canyon data define a thick sediments in the basins and thinner, disrupted sediments in the structural high separating the basins. There is a rich pattern of unconformities, pinch-outs, on-laps, and faults between the basin centers and edges. The Atwater Valley data reveal a more complicated seismic stratigraphy with many unconformable shallow reflections and sub-sea-floor diffractions. The vent/mound sites show abundant sea-floor diffractions, discontinuous reflections, zones of very strong amplitudes, zones of wash outs, and possible pull-downs. Both regions have abundant diffractions at the sea floor and within reflecting units, indicating the importance of post-cruise migration of the data. There are numerous amplitude anomalies and variations that are consistent with acoustic indicators of hydrate and related gas, but additional post cruise analysis is required to interpret and map these features.

The Knudsen bathymetry data were much more variable in quality and coverage, because of their dependence on the weather. During the middle portion of the cruise, when a strong southerly air flow generated a short swell and sea state, the bathymetry rarely functioned robustly. This was probably due to the location of the transducers on the bow of the Gyre where the pitch and roll of the ship created maximum cavitation and bubble interference.

Each of the objectives laid out prior to the cruise was either fully met or is expected to be met with additional post cruise processing, analysis, and interpretation of the seismic data.

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Figure Captions

Figure 1: Map showing bathymetry in the northern Gulf of Mexico, locations of survey areas (Keathley Canyon 195 and Atwater Valley 14), and selected pre-existing data sets that were used in cruise G1-03-GM.

Figure 2: Detailed map of the Keathley Canyon region showing USGS track lines collected during G1-03-GM. Data from highlighted lines KC1 and KC9 are shown in Figures 3, 4, 5, 6, and 7. The black box outlines lease block KC195.

Figure 3: Example of stacked MCS profile using15-in^3 water gun source. This line is labeled line Test2, and is coincident with KC1. Data are from the central portion of the line and are directly comparable to the data shown in figures 4 and 5. CDPs are 5 m apart. Vertical scale gives two-way travel time with tic-lines at every .25 s.

Figure 4: Example of stacked MCS profile using 13/13-in^3 GI gun source (line KC1). Data are from the central portion of the line and are directly comparable to the data shown in figures 3 and 5. CDPs are 5 m apart. Vertical scale gives two-way travel time with tic-lines at every .25 s.

Figure 5: Example of stacked MCS profile using 24/24-in^3 GI gun source (line KC59). This line is KC59 and is coincident with KC1. Data are from the central portion of the line, and are directly comparable to the data shown in figures 3 and 4. CDPs are 5 m apart. Vertical scale gives two-way travel time with tic-lines at every .25 s.

Figure 6: Example of stacked MCS profile in the Keathley Canyon site along line KC9. The source is the 13/13-in^3 GI gun. CDPs are 5 m apart. Vertical scale gives two-way travel time with tic-lines at every .25 s.

Figure 7: Example of bathymetric data taken using the Knudsen system along line KC1 in the Keathley Canyon region. This portion of the line is from the start of line Test2, and is located coincident with the west central portion of KC1. Horizontal tic marks are 2-minute time markers. Vertical scale is two-way travel time with tic lines shown every 10 ms. Data are highly vertically exaggerated: horizontal distance shown is about 5 km; vertical distance shown is about 75 m. Vertical noise bursts randomly across the record are interference from the GI gun shots.

Figure 8: Detailed map of the Atwater Valley region showing USGS track lines collected during G1-03-GM. Data from highlighted line AV97 is shown in Figure 9. The black box outlines lease block AV14.

Figure 9: Example of stacked MCS profile in the Atwater Valley site along line AV97. The source is the 13/13-in^3 GI gun. CDPs are 5 m apart. Vertical scale gives two-way travel time with tic-lines at every .25 s.

Appendix 1: G1-03-GM Multichannel Line Statistics

This appendix gives statistics and other information for each multichannel line from the cruise.

Table 1-1: Names and Statistics for Multichannel Lines

Line	Julian	FFID		Time		Line Length	Ave. Speed	Ship
	Day	Start	End	Start	End	(km)	(kts)	Azimuth
Test 1	123	1	1334	12:54	14:00	13.33	6.54	270
Test 2	123	1335	2876	14:35	16:45	15.41	3.84	90
Test 3	123	14	171		18:12	3.14		270
KC1	123	172	1403	18:13	21:45	24.62	3.76	270
KC2	123/124	1491	2549	22:12	2:00	21.16	3.01	90
KC3	124	2553	3199	3:10	4:59	12.92	3.84	270
KC4	124	1	649	5:38	7:34	12.96	3.62	90
KC5	124	650	1291	7:53	9:45	12.82	3.71	270
KC6	124	1292	1939	10:09	12:01	12.94	3.74	90
KC7	124	2049	2790	12:56	15:12	14.82	3.53	180
KC8	124	73	820	15:29	17:33	14.94	3.90	0
KC9	124	894	1647	17:52	20:08	15.06	3.59	180
KC10	124	1724	2478	20:27	22:33	15.08	3.88	0
KC11	124/125	35	791	22:52	1:07	15.12	3.63	180
KC12	125	938	1694	1:31	3:33	15.12	4.02	0
KC13	125	1863	2620	4:13	6:39	15.14	3.36	180
KC14	125	101	853	6:53	9:02	15.04	3.78	0
KC15	125	953	1711	9:25	11:31	15.16	3.90	180
KC16	125	1802	2558	11:43	13:54	15.12	3.74	0
KC17	125	150	908	14:24	16:49	15.16	3.39	180
KC18	125	1024	1763	17:08	19:14	14.78	3.80	0
KC19	125	1765	2097	20:44	21:47	6.64	3.42	180
KC20	125	45	400	22:02	23:03	7.10	3.77	0
KC21	125/126	459	772	23:24	0:25	6.26	3.33	180
KC22	126	869	1214	0:41	1:44	6.90	3.55	0
KC23	126	1352	1695	2:11	3:17	6.86	3.37	180
KC24	126	1704	1958	3:54	4:37	5.08	3.83	0
KC25	126	2013	2268	4:47	5:34	5.10	3.52	180
KC26	126	2336	2592	5:46	6:35	5.12	3.39	0
KC27	126	2645	2903	6:47	7:33	5.16	3.63	180
KC28	126	2959	3212	7:42	8:27	5.06	3.64	0
KC29	126	3541	3792	9:26	10:09	5.02	3.78	180
KC30	126	3918	4166	10:29	11:10	4.96	3.92	0
KC31	126	4321	4573	11:36	12:22	5.04	3.55	180
KC32	126	71	319	12:39	13:22	4.96	3.74	0
KC33	126	378	627	13:35	14:21	4.98	3.51	180
KC34	126	871	1122	15:02	15:46	5.02	3.70	90
KC35	126	1236	1484	16:07	16:49	4.96	3.83	270
KC36	126	1671	1920	17:24	18:10	4.98	3.51	90
KC37	126	2003	2228	18:26	19:10	4.50	3.31	270
KC38	126	2410	2659	19:44	20:29	4.98	3.59	90
KC39	126	2868	3022	21:04	21:45	3.08	2.43	270
KC40	126	3116	3366	22:00	22:44	5.00	3.68	90

KC41	126	3441	3683	23:02	23:45	4.84	3.65	270
KC42	127	3841	4089	0:11	0:54	4.96	3.74	90
KC43	127	4147	4398	1:05	1:44	5.02	4.17	270
KC44	127	4461	4706	1:55	2:35	4.90	3.97	90
KC45	127	4810	5058	2:52	3:35	4.96	3.74	270
KC46	127	5160	5379	3:56	4:33	4.38	3.84	90
KC47	127	5479	5724	5:10	5:52	4.90	3.78	270
KC48	127	5726	6371	7:12	9:06	12.90	3.67	90
KC49	127	6372	7008	9:24	11:07	12.72	4.00	270
KC50	127	7009	7653	11:26	13:14	12.88	3.86	90
KC51	127	7654	8301	13:35	15:20	12.94	3.99	270
KC52	127	8302	8951	15:54	17:51	12.98	3.59	90
KC53	127	1	644	18:39	20:35	12.86	3.59	270
KC54	127	645	1633	21:09	23:52	19.76	3.93	90
KC55	128	1634	2018	0:20	1:23	7.68	3.95	30
KC56	128	2099	2611	2:07	3:30	10.24	4.00	302
KC57	128	2612	3611	3:48	6:47	19.98	3.62	225
KC58	128	1	649	7:25	9:22	12.96	3.59	90
KC59	128	817	1607	13:23	16:54	23.70	3.64	270
KC60	128/129	1	2829	17:46	5:59	84.84	3.75	5
GB61	129	1	1572	7:35	14:44	47.13	3.56	87
GB62	129	1647	1919	15:42	16:48	8.16	4.01	327
GB63	129	1920	2157	17:42	18:59	7.11	2.99	196
AV64	130/131	2559	3001	23:22	0:33	8.84	4.05	140
AV65	131	3002	3273	1:04	1:49	5.42	3.90	320
AV66	131	3274	3527	2:11	2:51	5.06	4.08	140
AV67	131	3528	3772	3:18	3:54	4.88	4.39	180
AV68	131	3773	4013	4:04	4:46	4.80	3.70	0
AV69	131	4014	4260	5:04	5:46	4.92	3.80	180
AV70	131	4261	4507	5:57	6:38	4.92	3.89	0
AV71	131	4508	4755	6:59	7:37	4.94	4.21	180
AV72	131	4756	5003	8:15	8:54	4.94	4.10	0
AV73	131	5004	5254	9:21	10:03	5.00	3.86	180
AV74	131	5255	5500	10:16	10:54	4.90	4.18	0
AV75	131	5501	5747	11:18	11:58	4.92	3.99	180
AV76	131	5748	6008	12:19	12:59	5.20	4.21	0
AV77	131	6145	6394	13:22	14:06	4.98	3.67	180
AV78	131	1	248	14:10	14:48	4.94	4.21	0
AV79	131	249	492	15:03	15:47	4.86	3.58	180
AV80	131	493	739	15:53	16:32	4.92	4.09	0
AV81	131	740	985	16:42	17:24	4.90	3.78	180
AV82	131	1281	1528	18:11	18:53	4.94	3.81	45
AV83	131	1541	1789	19:43	20:25	4.96	3.83	225
AV84	131	1790	2103	20:46	21:36	6.26	4.06	45
AV85	131	2104	2352	22:04	22:43	4.96	4.12	270
AV86	131	2394	2641	22:50	23:29	4.94	4.10	90
AV87	131/132	2642	2888	23:53	0:33	4.92	3.99	270
AV88	132	2889	3132	0:49	1:28	4.86	4.04	90
AV89	132	3133	3380	1:41	2:20	4.94	4.10	270
AV90	132	3381	3612	2:41	3:24	4.62	3.48	90
AV91	132	3613	3857	3:34	4:13	4.88	4.05	270
AV92	132	1	246	4:26	5:05	4.90	4.07	90
AV93	132	247	495	5:25	6:03	4.96	4.23	270

AV94	132	496	509	6:35	6:37	0.26	4.21	90
AV94b	132	510	1011	10:39	12:00	10.02	4.01	90
AV95	132	1012	1261	12:29	13:08	4.98	4.14	270
AV96	132	1262	1511	13:21	14:08	4.98	3.43	90
AV97	132	1512	1958	14:24	15:33	8.92	4.19	270
AV98	132	1595	2453	16:40	18:00	17.16	6.95	0
AV99	132	2454	3670	18:35	22:03	24.32	3.79	315
MC100	132/133	120	1306	22:32	1:44	23.72	4.00	246
MC101	133	1563	1834	2:25	3:08	5.42	4.08	338
					Total:	1032.66 km		

Table 1-2: Seismic Sources

Line[1]	Seismic Source
Test1	15 in^3 Water Gun
Test2	15 in^3 Water Gun
Test3	13/13 in^3 GI Gun (line turn)
KC1-KC58	13/13 in^3 GI Gun
KC59-GB63	24/24 in^3 GI Gun
AV64-MC101	13/13 in^3 GI Gun

[1] Test1 was a short line with vessel speed greater than 4 kts. Test2 is the entire line at 4 kts. Test3 was on the turn to reverse and reoccupy the line. Test4 became KC1 with the decision to use the 13/13 in^3 GI Gun for the main seismic source of the cruise.

Appendix 2: Summary of Digital Data from G1-03-GM

This appendix gives tables of the tapes, CD's and DVD's created on G1-03-GM. The official archive for metadata related to this cruise, including navigation, is at the Western Coastal and Marine Geology Team of the USGS in Menlo Park, California, in the InfoBank archive. The SEG-Y files of the stacked MCS data will be released in an Open File Report and available for download from the following web-site after USGS review and approval: http://walrus.wr.usgs.gov/reports. Copies of all CD's were taken separately to the Menlo Park, CA and Woods Hole, MA USGS offices.

Table 2-1: Summary of Multichannel Field Tapes

Tape No.	Line	start ffid	end ffid
1	Test1	586	1334
	Test2	1335	2876
2	Test3	14	171
	KC1	172	1403
	KC2	1491	2549
	KC3	2553	3199
3	KC4	1	649
	KC5	650	1291
	KC6	1292	1939
	KC7	2049	2790
4	KC8	73	820
	KC9	894	1647
	KC10	1724	2478
5	KC11	35	791
	KC12	938	1694
	KC13	1863	2620
6	KC14	101	853
	KC15	953	1711
	KC16	1802	2558
7	KC17	150	908
	KC18	1024	1763
	KC19	1765	2097
8	KC20	45	400
	KC21	459	772
	KC22	869	1214
	KC23	1352	1695
	KC24	1704	1958
	KC25	2013	2268
	KC26	2336	2592
	KC27	2645	2903
	KC28	2959	3212

	KC29	3541	3792
	KC30	3918	4166
	KC31	4321	4573
9	KC32	71	319
	KC33	378	627
	KC34	871	1122
	KC35	1236	1484
	KC36	1671	1920
	KC37	2003	2228
	KC38	2410	2659
	KC39	2868	3022
	KC40	3116	3366
	KC41	3441	3683
	KC42	3841	4089
	KC43	4147	4398
	KC44	4461	4706
10	KC45	4810	5058
	KC46	5160	5379
	KC47	5479	5724
	KC48	5725	6371
	KC49	6372	7008
	KC50	7009	7653
	KC51	7654	8301
	KC52	8302	8951
11	KC53	1	644
	KC54	645	1633
	KC55	1634	2018
	KC56	2099	2611
	KC57	2612	3611
12	KC58	1	649
	KC59	817	1607
13	KC60	1	2829
14	GB61	1	1572
	GB62	1647	1919
	GB63	1920	2157
15	AV64	2559	3001
	AV65	3002	3273
	AV66	3274	3527
	AV67	3528	3772
	AV68	3773	4013
	AV69	4014	4260
	AV70	4261	4507
	AV71	4508	4755
	AV72	4756	5003
	AV73	5004	5254

	AV74	5255	5500
	AV75	5501	5747
	AV76	5748	6008
	AV77	6145	6394
16	AV78	1	248
	AV79	249	492
	AV80	493	739
	AV81	740	985
	AV82	1281	1528
	AV83	1541	1789
	AV84	1790	2103
	AV85	2104	2352
	AV86	2394	2641
	AV87	2642	2888
	AV88	2889	3132
	AV89	3133	3380
	AV90	3381	3612
	AV91	3613	3857
17	AV92	1	246
	AV93	247	495
	AV94	510	1011
	AV95	1012	1261
	AV96	1262	1511
	AV97	1512	1958
	AV98	1959	2453
	AV99	2454	3670
18	MC100	120	1307
	MC101	1563	1834
	GunTest	1883	1993

Table 2-2: Summary of MCS SEG-Y data Archive DVDs

Disk	Lines	Description[1]
1	Test1 - KC06	Raw shot records
2	KC07 - KC15	Raw shot records
3	KC16 - KC31	Raw shot records
4	KC32 - KC50	Raw shot records
5	KC51 - KC58	Raw shot records

6	KC59-GB63	Raw shot records
7	AV64-AV86	Raw shot records
8	AV87-AV99	Raw shot records
9	MC100-MC101	Raw shot records
10	Test1-KC17	CDP sorted data
11	KC18-KC55	CDP sorted data
12	KC56-AV85	CDP sorted data
13	AV86-MC101	CDP sorted data
14	All Lines	Stacked data

[1] Raw shot records: 0.5 ms sample interval
CDP sorted data with geometry in headers: 1.0 ms sample interval
Stacked data: 1.0 ms sample interval

Table 2-3: Summary of Knudsen Bathymetric Data

Disk	Type	Date	Time	File Size	File Name	Good/No Good
1	CDROM	5/2/2003	8:15 PM	15054948	L1F1.SEG	OK
		5/2/2003	8:44 PM	10793340	L1F2.SEG	OK
		5/2/2003	9:14 PM	7183188	L1F3.SEG	OK
		5/2/2003	9:40 PM	8065368	L1F4.SEG	OK
		5/3/2003	2:42 AM	81381312	TEST4.SEG	
		5/3/2003	4:05 AM	28,070,49	6 KC2.SEG	
		5/3/2003	6:57 AM	43203276	KC2F2.SEG	OK
		5/3/2003	9:56 AM	40923180	KC3.SEG	OK
		5/3/2003	12:30 PM	42931836	KC4.SEG	OK
		5/3/2003	2:42 PM	41846076	KC5.SEG	OK
		5/3/2003	3:05 PM	57172	KC6.SEG	NG
		5/3/2003	3:13 PM	2636568	KC6_1.SEG	OK
		5/3/2003	3:35 PM	2039400	KC6F2.SEG	OK
		5/3/2003	3:35 PM	184314	KC6F2_1.SEG	NG
		5/3/2003	3:49 PM	5432400	KC6F2_2.SEG	Maybe
		5/3/2003	4:57 PM	20103732	KC6F3.SEG	NG
		5/3/2003	10:29 PM	44099028	KC8.SEG	OK
		5/4/2003	1:05 AM	49663548	KC9.SEG	Maybe
		5/4/2003	3:29 AM	50233572	KC10.SEG	OK
		5/4/2003	6:03 AM	55268784	KC11.SEG	NG
		5/4/2003	8:29 AM	46175544	KC12.SEG	OK

		5/4/2003	9:46 AM	14457780	KC13_0.SEG	NG
		5/4/2003	9:46 AM	57172	KC13_1.SEG	NG
		5/4/2003	9:46 AM	17172	KC13_2.SEG	NG
		5/4/2003	9:47 AM	325032	KC13_3.SEG	NG
		5/4/2003	9:57 AM	4238064	KC13_4.SEG	NG
		5/4/2003	9:57 AM	57172	KC13_5.SEG	NG
		5/4/2003	9:58 AM	519336	KC13_6.SEG	NG
		5/4/2003	9:58 AM	57172	KC13_7.SEG	NG
		5/4/2003	10:13 AM	5961708	KC13_8.SEG	NG
		5/4/2003	10:13 AM	57172	KC13_9.SEG	NG
		5/4/2003	10:20 AM	2663712	KC13_10.SEG	NG
		5/4/2003	10:20 AM	57172	KC13_11.SEG	NG
		5/4/2003	10:25 AM	2147976	KC13_12.SEG	NG
		5/4/2003	10:25 AM	217888	KC13_13.SEG	NG
		5/4/2003	10:28 AM	1157220	KC13_14.SEG	NG
		5/4/2003	10:28 AM	271460	KC13_15.SEG	NG
		5/4/2003	10:28 AM	71460	KC13_16.SEG	NG
		5/4/2003	10:29 AM	57172	KC13_17.SEG	NG
		5/4/2003	10:29 AM	166464	KC13_18.SEG	NG
		5/4/2003	10:29 AM	57172	KC13_19.SEG	NG
		5/4/2003	11:35 AM	23401728	KC13_20.SEG	NG
		5/4/2003	1:59 PM	46107684	KC14.SEG	OK
2	CDROM	5/4/2003	4:28 PM	47926332	kc15.seg	NG
		5/4/2003	6:50 PM	46772712	kc16.seg	Maybe
		5/4/2003	9:46 PM	52798680	kc17.seg	NG
		5/5/2003	12:19 AM	47777040	kc18.seg	OK
		5/5/2003	2:43 AM	23496732	kc19.seg	NG
		5/5/2003	4:00 AM	23252436	kc20.seg	Maybe
		5/5/2003	5:24 AM	23808888	kc21.seg	NG
		5/5/2003	6:40 AM	23971752	kc22.seg	OK
		5/5/2003	8:14 AM	26007552	kc23.seg	NG
		5/5/2003	9:34 AM	17579340	kc24.seg	OK
		5/5/2003	10:30 AM	17552196	kc25.seg	NG
		5/5/2003	11:32 AM	19492992	kc26.seg	OK
		5/5/2003	12:29 PM	17307900	kc27.seg	NG
		5/5/2003	1:24 PM	16914312	kc28.seg	OK
		5/5/2003	3:05 PM	16018560	kc29.seg	Maybe
		5/5/2003	4:06 PM	14878512	kc30.seg	OK
		5/5/2003	5:19 PM	17226468	kc31.seg	Maybe
		5/5/2003	6:19 PM	16317144	kc32.seg	OK
		5/5/2003	7:18 PM	17036460	kc33.seg	Maybe
		5/5/2003	8:43 PM	16493580	kc34.seg	NG
		5/5/2003	9:46 PM	15937128	kc35.seg	Maybe
		5/5/2003	11:07 PM	16737876	kc36.seg	NG
		5/6/2003	12:06 AM	15367104	kc37.seg	NG
		5/6/2003	1:26 AM	15801408	kc38.seg	NG
		5/6/2003	2:41 AM	14498496	kc39.seg	NG
		5/6/2003	3:40 AM	15353532	kc40.seg	NG
		5/6/2003	4:42 AM	15312816	kc41.seg	NG
		5/6/2003	5:51 AM	16615728	kc42.seg	NG

		5/6/2003	6:41 AM	14824224	kc43.seg	Maybe
		5/6/2003	7:32 AM	15163524	kc44.seg	NG
		5/6/2003	8:32 AM	16262856	kc45.seg	OK
		5/6/2003	9:29 AM	14213484	kc46.seg	
3	CDROM	5/6/2003	10:48 AM	16127136	KC47.SEG	OK
		5/6/2003	2:02 PM	42958980	KC48.SEG	NG
		5/6/2003	4:03 PM	38615940	KC49.SEG	OK
		5/6/2003	6:10 PM	40896036	KC50.SEG	NG
		5/6/2003	8:16 PM	38493792	KC51.SEG	OK
		5/6/2003	10:47 PM	41764644	KC52.SEG	NG
		5/7/2003	1:31 AM	38928096	KC53.SEG	OK
		5/7/2003	4:49 AM	58146048	KC54.SEG	NG
		5/7/2003	6:20 AM	22424544	KC55.SEG	NG
		5/7/2003	8:27 AM	29739852	KC56.SEG	OK
		5/7/2003	11:43 AM	64932048	KC57.SEG	NG
		5/7/2003	2:19 PM	42008940	KC58.SEG	NG
		5/7/2003	9:50 PM	80132688	KC59.SEG	
4	CDROM	5/9/2003	12:59 AM	247543308	kc60.seg	OK
		5/9/2003	1:00 AM	271460	kc60_1.seg	NG
		5/9/2003	1:00 AM	67172	kc60_2.seg	NG
		5/9/2003	1:02 AM	108924	kc60_3.seg	NG
		5/9/2003	1:02 AM	4506	kc60_4.seg	NG
		5/9/2003	1:02 AM	24318	kc60_5.seg	NG
		5/9/2003	2:39 AM	39389544	kc60_6.seg	OK
		5/9/2003	2:39 AM	30506	kc60_7.seg	NG
		5/9/2003	2:39 AM	30744	kc60_8.seg	NG
		5/9/2003	2:39 AM	57412	kc60_9.seg	NG
		5/9/2003	2:55 AM	6613164	kc60_10.seg	OK
		5/9/2003	11:40 AM	174553092	gb61.seg	NG
		5/9/2003	1:44 PM	26916876	gb62.seg	OK
		5/9/2003	3:56 PM	31707792	gb63.seg	NG
		5/10/2003	9:29 PM	64596128	av64.seg	OK
		5/10/2003	10:13 PM	11988804	av65.seg	OK
		5/10/2003	10:14 PM	918404	av65_1.seg	OK
		5/10/2003	10:15 PM	540752	av65_2.seg	OK
		5/10/2003	10:45 PM	12259116	av65_3.seg	OK
		5/10/2003	11:48 PM	16656444	av66.seg	OK
		5/11/2003	12:52 AM	15462108	av67.seg	OK
		5/11/2003	1:42 AM	16805736	av68.seg	OK
		5/11/2003	2:42 AM	17185752	av69.seg	OK
		5/11/2003	3:34 AM	16520724	av70.seg	OK
		5/11/2003	4:34 AM	15529968	av71.seg	OK
		5/11/2003	5:51 AM	16194996	av72.seg	OK
5	CDROM	5/11/2003	5:59 AM	17267184	av73.seg	OK
		5/11/2003	6:50 AM	15054948	av74.seg	OK
		5/11/2003	7:54 AM	16235712	av75.seg	OK
		5/11/2003	8:55 AM	16778592	av76.seg	OK
		5/11/2003	9:05 AM	3695184	av76_1.seg	OK
		5/11/2003	10:02 AM	17633628	av77.seg	OK
		5/11/2003	10:45 AM	15462108	av78.seg	OK

		5/11/2003	11:42 AM	17294328	av79.seg	OK
		5/11/2003	12:28 PM	15923556	av80.seg	OK
		5/11/2003	1:51 PM	29889144	av81.seg	OK
		5/11/2003	2:49 PM	16927884	av82.seg	OK
		5/11/2003	4:21 PM	16656444	av83.seg	OK
		5/11/2003	5:33 PM	19330128	av84.seg	OK
		5/11/2003	6:40 PM	16222140	av85.seg	OK
		5/11/2003	7:26 PM	15869268	av86.seg	OK
		5/11/2003	8:30 PM	16140708	av87.seg	OK
		5/11/2003	9:24 PM	15597828	av88.seg	OK
		5/11/2003	10:17 PM	16018560	av89.seg	OK
		5/11/2003	11:20 PM	17104320	av90.seg	OK
		5/12/2003	12:09 AM	15665688	av91.seg	OK
		5/12/2003	1:02 AM	15570684	av92.seg	OK
		5/12/2003	2:00 AM	15733548	av93.seg	OK
		5/12/2003	3:18 AM	19045116	av94.seg	OK
		5/12/2003	4:32 AM	16344288	av94R.seg	OK
		5/12/2003	7:56 AM	10372608	av94ext.seg	OK
		5/12/2003	9:05 AM	15489252	av95.seg	OK
		5/12/2003	10:05 AM	18922968	av96.seg	OK
		5/12/2003	11:29 AM	27324036	av97.seg	OK
		5/12/2003	1:57 PM	32657832	av98.seg	OK
		5/12/2003	6:00 PM	84652164	av99.seg	OK
		5/12/2003	6:28 PM	7658208	av99_1.seg	OK
		5/12/2003	9:40 PM	77974740	mc100.seg	OK
		5/12/2003	11:05 PM	17552196	mc101.seg	OK

Table 2-4: Summary of Navigation Data

Disk	Type	Description
1	CDROM	YoNav Navigation Files
2	CDROM	Navigation Imagery

Appendix 3: Marine Mammal Documents

Documents included in this Appendix are:

(1) Permit from National Marine Fisheries Service (NMFS)
(2) Cover letter for application to NMFS
(3) Submission to NMFS "Request by the U.S. Geological Survey for an Incidental Harassment Authorization to conduct a survey in the Gulf of Mexico"
(4) Final Report submitted by Marine Mammal Observers
(5) Submission to Minerals Management Service "Application for permit to conduct geological or geophysical exploration for mineral resources or scientific research in the outer continental shelf"
(6) Notice to MMS of completion of work

Note: Contents of this appendix are not complete.

Coastal and Marine Geology Program
599 Seaport Blvd.
Redwood City, California 94063

Donald R. Knowles
National Marine Fisheries, Office of Protected Resources
1325 East West Highway
Silver Spring, Maryland 20910

January 14 2003

Dear Mr. Knowles,

The U.S. Geological Survey hereby requests an Incidental Harassment Authorization from the National Marine Fisheries Service to allow the incidental harassment of marine mammals that may occur while collecting marine high-resolution seismic-reflection data offshore in the Gulf of Mexico. The data collected will be used to support an on going Gas-Hydrates study. Gas hydrates are methane ice substances found at the sea floor and in shallow sub-bottom sediments on continental margins in water depths greater than about 500 m. The USGS research program is investigating the occurrence and distribution of naturally occurring marine gas hydrates in the Gulf of Mexico in order to understand the hazard they pose to deep-water drilling and the potential they offer as an energy resource. As part of this study, we wish to acquire high-resolution seismic reflection data to better image and therefore understand the geologic structure and stratigr aphy in areas where gas hydrate has been recovered by seafloor coring programs and where an industry-funded research well will be drilled in early 2004.

The survey is scheduled to start the 1st of May 2003 and end the 14th of May. The ship will be the Research Vessel Gyre. We are planning on working 24 hours a day 7 days a week.

The USGS has conducted multiple geophysical surveys under the supervision of marine-mammal biologists. Acoustic sources have been shut off when marine mammals entered safety zones that have been stipulated by NMFS and we have followed procedures as stated in our permit when mammals left these zones to re-start seismic systems. We believe we have been responsible in the operation of acoustic systems when conducting seismic-reflection surveys. We appreciate your consideration of the attached request for an Incidental Harassment Authorization.

Sincerely

David Hogg, Chief of the USGS Marine Support Facility
599 Seaport Blvd.
Redwood City, Calif. 94063
Tel (650) 329-5864
Fax (650) 365-9841

Request by the U.S. Geological Survey for an Incidental Harassment Authorization to conduct a survey in the Gulf of Mexico

Summary Request

The U.S. Geological Survey (USGS) hereby requests an Incidental Harassment Authorization from the National Marine Fisheries Service to allow the incidental harassment of marine mammals that may occur while collecting marine high-resolution seismic-reflection data offshore in the Gulf of Mexico. The data collected will be used to support an on going Gas-Hydrates study. Gas hydrates are methane-ice substances found at the sea floor and in shallow sub-bottom sediments on continental margins in water depths greater than about 500 m. The USGS research program is investigating the occurrence and distribution of naturally occurring marine gas hydrates in the Gulf of Mexico in order to understand the hazard they pose to deep-water drilling and the potential they offer as an energy resource. As part of this study, we wish to acquire high-resolution seismic reflection data to better image and therefore understand the geologic structure and stratigraphy in areas where gas hydrate has been recovered by seafloor coring programs and where an industry-funded research well will be drilled in early 2004.

The five seismic sources to be utilized under this request are a Huntec boomer (peak frequency of 4.5 kHz); Edgetech sub-bottom profiler (peak frequency of 5.75 kHz), Benthos SIS-1000 side scan sonar (operating frequency of 100khz) and sub-bottom profiler (operating at a swept frequency of 2khz to 5khz), 15 in3 water gun (peak frequencies less than 500 Hz) and a 35-in3 Generator-Injector (GI) gun (peak frequencies less than 500 Hz). This study should result in no taking of marine mammals. The likelihood of incidental harassment, while not impossible, is unlikely given the frequencies and low energy levels of the sources. The USGS proposes to have trained mammal observers on board the research vessel and to abide by zones of impact set at 20 m, 20 m, 20 m, 30 m, and 30 m respectively (for the five seismic sources) for mysticetes and odontocetes. Work will be conducted 24 hours a day.

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(1) A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals;

The U.S. Geological Survey proposes to conduct a high-resolution seismic-reflection survey offshore in the Gulf of Mexico for approximately fourteen days at the beginning of May 2003. The seismic reflection data will be collected using three basic systems:

1) Huntec boomer sound source to collect high-resolution seismic-reflection data of the sub-sea floor;
2) Edgetech 512I sub-bottom profiler to collect high-resolution seismic-reflection data of the sub-sea floor;
3) Data Sonics SIS-1000 side scan sonar with a sub-bottom profiler; and
4) A high-resolution multi-channel system for which the primary source will be a 15-in^3 water gun or 35-in^3 GI gun. A 250-m-long hydrophone streamer is used for the multi-channel system.

The high-resolution **Huntec™** boomer system uses an electrically powered sound source that is towed behind the ship at depths between 30 m and 160 m below the sea surface. The hydrophone arrays for listening are attached to the tow vehicle that houses the sound source. We plan to use the Huntec™ primarily in water depths greater than 300 m. The system is triggered at 0.5 to 1.25 second intervals, depending upon the source tow depth. The sound pressure level (SPL) for this unit is 205 dB re 1 µPa-m RMS. The output-sound bandwidth is 0.5 kHz to 8 kHz, with the main peak at 4.5 kHz. The estimated zone of impact, including absorption calculations (Richardson et al., 1995, p. 73) using 4.5 kHz as the peak frequency at 160 dB is 175 meters and at 180 dB is 17 meters.

The **Edgetech** 512I Chirp is a high resolution seismic system. The system is towed either at the water surface or slightly submerged, depending on the application and water depth. The 512I has a sound pressure level (SPL) of 198 dB re 1µ Pa-m RMS. It has a frequency range of 500hz to 12kHz with pulse widths from 5 ms to 50 ms depending on the application. Using the center frequency of 5.75 kHz the estimated zone of impact at 160 dB including absorption calculations (Richardson et al., 1995, p.73) is 75 meters and at 180 dB is 8 meters.

The **SIS-1000** is a chirp side scan sonar and sub-bottom profiler. It is towed behind the ship at depths of 1 to 700 meters depending on the depth of the water. The side scan frequency is a 100-khz band swept FM and the sub-bottom profiler is a 2kHz to 5kHz swept FM band. The side scan system measures the return time and the intensity of echoes to create a high-resolution image of the sea floor similar to an air photo on land. The sub-bottom profiler is another tool used to collect high-resolution data of the sub-sea floor. The sub-bottom profiler is synchronous with side scan.

The side scan has a sound pressure level (SPL) of 225 dB re 1µ Pa-m RMS that radiates at .5° horizontal at a 70°'s vertical angle. The estimated zone of impact using absorption calculations (Richardson et al., 1995, p.73) for 160 dB is 375 meters and 180 dB is 105 meters. This sound is a very focused beam and not a 360° pattern. The sub-bottom profiler has a sound pressure level of 207dB re 1µPa-m RMS. Using a center frequency of 4.5 kHz the estimated zone of impact using absorption calculations (Richardson et al., 1995, p. 73) for 160 dB is 250 meters and 180 dB is 25 meters. This is a 45° conical beam looking downward from the tow fish.

The multichannel system has two potential pneumatic sources: 15-in^3 water gun or 35-in^3 GI gun. The larger source, the **35-in^3 GI gun** is a special type of small air gun called a generator-injector, or GI gun (trademark of Seismic Systems, Inc., Houston, TX). This is a dual chamber gun that will have inserts installed to reduce it from a 35-in3 to a 24-in3 gun. This type of air gun consists of two small air guns within a single steel body. The two small air guns are fired sequentially, with the precise timing required to nullify the bubble oscillations that typify sound pulses from a single air gun of common type. These oscillations impede detailed analysis of the sub-surface. For arrays consisting of many air guns, bubble oscillations are cancelled by careful selection of air gun sizes. The GI gun is a mini-array that is carefully adjusted to achieve the desired bubble cancellation. Air guns and GI guns with similar chamber sizes have similar peak output pressures. The GI gun for this survey has two chambers of equal size-24-in3 and the gun will be fired every 10 seconds. Compressed air delivered to the GI gun will have a pressure between 2000 and 3000 psi. The gun will be towed 5 meters behind the vessel and suspended from a float to maintain a depth of about 1 m.

The manufacturer's literature indicates that a GI gun of the size we will use has a sound-pressure level (SPL) of about 208 dB re 1 µPa-m RMS. The GI gun's output sound pulse has a duration of about 10 ms. The amplitude spectrum of this pulse, as shown by the manufacturer's data, indicates that most of the sound energy is at frequencies below 500 Hz. Field measurements by USGS personnel indicates that the GI gun outputs low sound amplitudes at frequencies above 500 Hz. Thus high-amplitude sound from this source is at frequencies that are outside the main hearing band of odontocetes and pinnipeds (Richardson et al. 1995, p. 205-240). Using a peak frequency of 500 Hz the estimated zone of impact at 160 dB including absorption calculations (Richardson et al.,1995, p.73) is 250 meters and at 180 dB is 25 meters.

The smaller sound source for the multi-channel system is a **Type S15 T Water Gun** manufactured by Seismic Systems Inc. This type of gun stores high pressure air in the air chambers that when fired, forces water that is stored in the water chamber out through four ports generating an acoustical signal of implosive type. The used air exhausts through two lateral pipes. The gun is towed from 0.5 meters to 3 meters deep and approximately 5 meters behind the ship. The system is operated with 3000 psi high pressure air. The water gun has a 15 cubic inch chamber and a peak frequency of less than 500 Hz (100 – 300 Hz) and will be fired at approximately 5 second intervals. Available information from the manufacturer for the small water gun is for firing at 1800 psi, somewhat lower than our proposed firing of 3000psi. At the lower pressure, the water gun has a peak frequency of 100-500 Hz, maximum energy at 190-200 Hz, a signal length of about 0.025 s (25ms), and a sound pressure level of 204 dB re 1µPa-m RMS. Using a frequency of 200 Hz the estimated zone of impact using absorption calculations (Richardson et al., 1995, p. 73) for 160dB is 170 meters and 180dB is 15 meters. The higher pressure will slightly increase the maximum energy, and shift the peak frequencies slightly higher, but not above 500Hz (Hutchinson, D.R., and Detrick, R.S., 1984, Water gun vs Air gun: a comparison: Marine Geophysical Researches, v. 6,p. 295-310).

In 1994, the Northeast NMFS approved the use of the 15 in3 water gun for profiling in Stellwagen Bank National Marine Sanctuary, a region where Right Whales, an endangered species, are often found.

(2) The date(s) and duration of such activity and the specific geographical region where it will occur;

The work is planned for approximately 14 days starting about the 1st of May and ending about the 14th of May 2003. The vessel will be the research vessel Gyre. The primary work area is between longitude 93 W and 89 W south of the 300 meter contour and north of the 2500 meter contour. We will be working 24 hours a day 7 days a week.

(3) The species and numbers of marine mammals likely to be found within the activity area;

Species of marine mammals	**Estimated Population**	Strategic Status	Notes (see below)
Sperm Whale Northern Gulf of Mexico Stock	530	YES	b,f
Dwarf Sperm Whale Northern Gulf of Mexico Stock	547	YES	a,b
Pygmy Sperm Whale Northern Gulf of Mexico Stock	547	YES	a,b
Byrde's Whale Northern Gulf of Mexico Stock	35	NO	b
Cuvier's Beaked Whale Northern Gulf of Mexico Stock	30	NO	b
Gervais' Beaked Whale Northern Gulf of Mexico Stock	?	NO	b,c
Bottlenose Dolphin Northern Gulf of Mexico Stock	4191	NO	d
Bottlenose Dolphin Eastern Gulf of Mexico Coastal Stock	9912	NO	d
Atlantic Spotted Dolphin Northern Gulf of Mexico Stock	3213	NO	b,e
Pantropical Spotted Dolphin Northern Gulf of Mexico Stock	31320	NO	b
Striped Dolphin Northern Gulf of Mexico Stock	4858	NO	b
Spinner Dolphin Northern Gulf of Mexico Stock	6316	NO	b
Rough-Toothed Dolphin Northern Gulf of Mexico Stock	852	NO	b
Clymene Dolphin Northern Gulf of Mexico Stock	5571	NO	b
Frasers Dolphin Northern Gulf of Mexico Stock	127	NO	b
Killer Whale Northern Gulf of Mexico Stock	277	NO	b
False Killer Whale Northern Gulf of Mexico Stock	381	NO	b
Pygmy Killer Whale Northern Gulf of Mexico Stock	518	NO	b
Melon-Headed Whale Northern Gulf of Mexico Stock	3965	NO	b
Risso's Dolphin Northern Gulf of Mexico Stock	2749	NO	b
Short-Finned Pilot Whale Northern Gulf of Mexico Stock	353	YES	b

Notes

a) Estimates of specific species of sperm whales abundance cannot be provided due to uncertainty of species identification at sea.
b) Source: Hansen et al. (1995) as reported in Waring et al.(2001)
c) Estimates may also include an unknown number of Cuvier beaked whales and abundance of Gervais beaked whale cannot be estimated due to uncertainty of species identification at sea.
d) Source: Blaylock and Hoggard (1994) as reported in Waring et al. (2001)
e) This could be an underestimate and should be considered a partial stock estimate because the continental shelf areas were not generally covered by either vessel or GulfCet aerial surveys.
f) This species is listed as endangered under the Endangered Species act (ESA).

(4) A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities;

Sperm Whale, Northern Gulf of Mexico Stock

Sperm whales are found throughout the world's oceans in deep waters from between about 60° N and 60° S latitudes (Leatherwood and Reeves 1983; Rice 1989). There has been speculation, based on year round occurrence of strandings, opportunistic sightings, and whaling catches, that sperm whales in the Gulf of Mexico may constitute a distinct stock (Schmidly 1981), but there is no information on stock differentiation. Seasonal aerial surveys confirm that sperm whales are present in the northern Gulf of Mexico in all seasons, but sightings are more common during the summer months (Mullin et al. 1991; Davis et al., in preparation). Seasonal GulfCet aerial surveys done between 1991 and 1994 showed an average estimated abundance of sperm whales for all surveys combined was 530 coefficient of variation (CV) = 0.31 (Hansen et al. 1995). This species is listed as endangered under the Endangered Species Act (ESA).

Dwarf Sperm Whale, Northern Gulf of Mexico Stock

The Dwarf sperm whale appears to be distributed worldwide in temperate to tropical waters (Caldwell and Caldwell 1989). Sightings of these animals in the northern Gulf of Mexico occur primarily along the continental shelf edge and over the deeper waters off the continental shelf (Mullin et al. 1991; Southeast Fisheries science Center, SEFSC, unpublished data). Dwarf sperm whales and pygmy sperm whales are difficult to distinguish and sightings of either species are often categorized as *Kogia* sp. Pygmy and dwarf sperm whales have been sighted in the northwestern Gulf of Mexico in waters 1000 m deep, on average (Davis et al. 1998). However, these authors cautioned that inferences on preferred bottom depths should await surveys for the entire Gulf of Mexico. Estimated average abundance of *Kogia* sp. by surveys done from 1991 through 1994 is 547 (Hansen et al. 1995). Estimates of specific species of sperm whales abundance cannot be provided due to uncertainty of species identification at sea. This species is not listed under the Endangered Species Act.

Pygmy Sperm Whale, Northern Gulf of Mexico Stock

The Pygmy sperm whale appears to be distributed worldwide in temperate to tropical waters (Caldwell and Caldwell 1989). Sightings of these animals in the northern Gulf of Mexico occur primarily along the continental shelf edge and over the deeper waters off the continental shelf (Mullin et al. 1991;

Southeast Fisheries science Center, SEFSC, unpublished data). Dwarf sperm whales and pygmy sperm whales are difficult to distinguish and sightings of either species are often categorized as *Kogia* sp. Pygmy and dwarf sperm whales have been sighted in the northwestern Gulf of Mexico in waters 1000 m deep, on average (Davis et al. 1998). However, these authors cautioned that inferences on preferred bottom depths should await surveys for the entire Gulf of Mexico. Estimated average abundance of *Kogia* sp. by surveys done from 1991 through 1994 is 547 (Hansen et al. 1995). Estimates of specific species of sperm whales abundance cannot be provided due to uncertainty of species identification at sea. This species is not listed under the Endangered Species Act.

<u>Byrde's Whale, Northern Gulf of Mexico Stock</u>

Brydes's whales are considered the tropical and sub tropical baleen whale of the worlds oceans. It is postulated that the Bryde's whales found in the Gulf of Mexico may represent a resident stock (Schmidly 1981; Leatherwood and Reeves 1983), but there is no information on stock differentiation. Most sightings of Bryde's whales have occurred during the spring-summer months Hansen et al. 1995; Davis et al. in preparation), but strandings have occurred throughout the year (Jefferson et al. 1992). Data collected on vessel surveys during 1991 – 1994 spring-summer in the northern Gulf of Mexico was used to estimate an average abundance for all surveys as 35 (CV=1.10) (Hansen et al. 1995) and was based on three sightings all of which occurred in 1991. This species is not listed under the Endangered Species Act.

<u>Cuvier's Beaked Whale , Northern Gulf of Mexico Stock</u>

Cuvier's beaked whales are distributed throughout the world's oceans except for the polar regions (Leatherwood and Reeves 1983; Heyning 1989). Beaked whales were seen in all seasons during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico (Davis et al., in preparation). Some of the aerial sightings may have included Curvier's beaked whale, but identification of beaked whale species from aerial surveys is problematic. Data collected on vessel surveys during 1991 – 1994 spring-summer in the northern Gulf of Mexico was used to estimate an average abundance for all surveys as 30 (CV=0.50) (Hansen et al. 1995). The estimated abundance of Curvier's beaked whales is 30 (CV=0.50) (Hansen et al. 1995).

<u>Gervais' Beaked Whale, Northern Gulf of Mexico Stock</u>

Beaked whales were seen in all seasons during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico (Davis et al., in preparation). Abundance estimates of Gervais' beaked whales are uncertain due to species identification at sea. This species is not listed under the Endangered Species Act.

Bottlenose Dolphin, Northern Gulf of Mexico Coastal Stock

The northern Gulf of Mexico coastal bottlenose dolphin stock has been defined for management purposes as those bottlenose dolphins occupying the nearshore coastal waters in the U.S. Gulf of Mexico from the Mississippi River mouth to approximately 84°W longitude, from shore, barrier islands, or presumes bay boundries to 9.3 km seaward of the 18.3 m isobath. The northern coastal stock area is characterized by temperate climate, barrier islands, sand beaches, coastal marshes and marsh islands, and has a relatively high level of fresh water input from rivers and streams. The abundance estimate is 4,191 dolphins with coefficient of variation (CV) = 0.21 (Blaylock and Hoggard 1994). This species is not listed as threatened or endangered under the Endangered Species Act.

Bottlenose Dolphin, Eastern Gulf of Mexico Coastal Stock

The eastern Gulf of Mexico coastal bottlenose dolphin stock has been defined for management purposes as the bottlenose dolphins occupying the area which extends from approximately 84° W Longitude to Key West, Florida from shore barrier islands, or presumed bay boundaries to 9.3 km seaward of the 18.3 m isobath. The eastern coastal stock area is temperate to subtropical in climate, is bordered by a mixture of coastal marshes, sand beaches, marsh and mangrove islands, and has an intermediate level of freshwater input. The abundance estimate is 9,912 dolphins with coefficient of variation (CV) =0.12.). This species is not listed as threatened or endangered under the Endangered Species Act.

Atlantic Spotted Dolphin, Northern Gulf of Mexico Stock

The Atlantic spotted dolphin is endemic to the Atlantic Ocean in warm temperature to tropical waters (Perrin et al. 1987,1994). Sightings of this species are concentrated along the continental shelf edge and also occur over the continental shelf in northern Gulf of Mexico[Fritts et al. 1983; Mullin et al. 1991; Southeast Fisheries Science Center (SEFSC) unpublished data]. Atlantic spotted dolphins were seen in all seasons during recent GulfCet aerial surveys of the northern Gulf of Mexico during 1993-1995 (Davis et al., in preparation). An average abundance estimate for all surveys combined is 3,213 (CV = 0.44) (Hansen et al. 1995). This could be an underestimate and should be considered a partial stock estimate because the continental shelf areas were not generally covered by either vessel or GulfCet aerial surveys. This species is not listed under the Endangered Species Act.

Pantropical Spotted Dolphin, Northern Gulf of Mexico Stock

The Pantropical spotted dolphin is distributed worldwide in tropical and some sub-tropical oceans (Perrin et al. 1987; Perrin and Hohn 1994). Sightings of this species occurred over the deeper waters of the northern Gulf of Mexico, and rarely over the continental shelf or continental shelf edge [Mullin et al. 1991; Southeastern Fisheries Science Center (SEFSC) unpublished data].Pantropical spotted dolphins were seen in all seasons during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993-1995 (Davis et al., in preparation). An average abundance estimate for all surveys combined is 31,320 (CV = 0.20) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Striped Dolphin, Northern Gulf of Mexico Stock

The striped dolphin is distributed worldwide in tropical to warm temperate oceanic waters (Leatherwood and Reeves 1983; Perrin et al. 1994). Sightings of these animals in the northern

Gulf of Mexico occur primarily over the deeper waters off the continental shelf [Mullin et al. 1991; Southeastern Fisheries Science Center (SEFSC) unpublished data]. Striped dolphins were seen in fall, winter, and spring during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993 – 1995 (Davis et al., in preparation). An average abundance estimate for all surveys combined is 4,858 (CV = 0.44) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Spinner Dolphin, Northern Gulf of Mexico Stock

The spinner dolphin is distributed worldwide in tropical to warm temperate waters in the world's oceans (Leatherwood and Reeves 1983; Perrin and Gilpatrick 1994). Sightings of these animals in the northern Gulf of Mexico occur primarily over the deeper waters off the continental shelf [Southeastern Fisheries Science Center (SEFSC) unpublished data]. Spinner dolphins were seen in winter, spring and summer during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993 – 1995 (Davis et al., in preparation). An average abundance estimate for all surveys combined is 3,316(CV = 0.43) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Rough-Toothed Dolphin, Northern Gulf of Mexico Stock

The rough-toothed dolphin is distributed worldwide in tropical to warm temperate waters (Leatherwood and Reeves 1983; Miyazaki and Perrin 1994). Sightings of these animals in the northern Gulf of Mexico occur primarily over the deeper waters off the continental shelf [Southeastern Fisheries Science Center (SEFSC) unpublished data]. Rough-toothed dolphins were seen in all seasons during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993 – 1995 (Davis et al., in preparation). An average abundance estimate for all surveys combined is 852 (CV = 0.31) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Clymene Dolphin, Northern Gulf of Mexico Stock

The Clymene dolphin is distributed worldwide in tropical and sub-tropical waters of the Atlantic (Leatherwood and Reeves 1983; Perrin and Mead 1994). Sightings of these animals in the northern Gulf of Mexico occur primarily over the deeper waters off the continental shelf (Mullin et al. 1994). Clymene dolphins were seen in the winter, spring and summer during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993 – 1995 (Davis et al., in preparation). An average abundance estimate for all surveys combined is 5,274(CV = 0.37) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Fraser's Dolphin, Northern Gulf of Mexico Stock

Fraser's dolphin is distributed worldwide in tropical waters (Perrin et al. 1994). Sightings of these animals in the northern Gulf of Mexico occur primarily over the deeper waters off the continental shelf (Leatherwood et al. 1993). Fraser's dolphins have been observer recently in the northern Gulf of Mexico during the spring, summer, and fall (Leatherwood et al. 1993), and also were seen in the winter during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993 – 1995 (Davis et al. in preparation). An average abundance estimate for all vessel surveys combined is 127 (CV = 0.90) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Killer Whale, Northern Gulf of Mexico Stock

The killer whale is distributed worldwide from tropical to polar regions (Leatherwood and Reeves 1983). Sightings of these animals in the northern Gulf of Mexico occur primarily over the deeper waters off the continental shelf [Southeast Fisheries Science Center (SEFSC) unpublished data]. Killer whales were seen only in the summer during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993 – 1995 (Davis et al., in preparation) and in the late spring during vessel surveys (SEFSC unpublished data). An average abundance estimate for all surveys combined is 277 (CV = 0.42) (Hansen et al. 1995).

False Killer Whale, Northern Gulf of Mexico Stock

The false killer whale is distributed worldwide throught warm temperate and tropical oceans (Leatherwood and Reeves 1983). Sightings of this species in the northern Gulf of Mexico occur primarily over the deeper waters off the continental shelf [Southeast Fisheries Science Center (SEFSC) unpublished data]. False killer whales were seen only in the summer during recent seasonal GulfCet aerial surveys of the northern Gulf of mexico during 1993 – 1995 (Davis et al., in preparation) and in late spring during vessel surveys (NMFS unpublished data). An average abundance estimate for all surveys combined is 381 (CV = 0.62) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Pygmy Killer Whale, Northern Gulf of Mexico Stock

The pygmy killer whale is distributed worldwide in tropical and sub-tropical waters (Ross and Leatherwood 1994). Sightings of these animals in the northern Gulf of Mexico occur primarily over the deeper waters off the continental shelf [Southeast Fisheries Science Center (SEFSC) unpublished data]. Sightings of this category were documented in all seasons during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993 – 1995 (Davis et al., in preparation). An average abundance estimate for all surveys combined is 518 (CV = 0.81) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Melon-Headed Whale, Northern Gulf of Mexico Stock

The melon-headed whale appears to be distributed worldwide in tropical to sub-tropical waters (Perryman et al. 1994). Sightings of these animals in the northern Gulf of Mexico occur primarily over the deeper waters off the continental shelf (Mullin et al. 1994). Sightings of this category were documented in all seasons during recent seasonal GulfCet aerial surveys of he northern Gulf of Mexico during 1993 – 1995 (Davis et al., in preparation). An average abundance estimate for all surveys combined is 3,965 (CV = 0.39) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Risso's Dolphin, Northern Gulf of Mexico Stock

Risso's dolphin is distributed worldwide in tropical to warm waters (Leatherwood and Reeves 1983). Sightings of these animals in the northern Gulf of Mexico occur primarily along the continental shelf and continental slope (Mullin et al. 1991; Southeast Fisheries Science Center, SEFSC, unpublished data). Risso's dolphin were seen in all seasons during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993-1995 (Davis et al., in preparation) and in the late spring during vessel surveys (SEFSC, unpublished data). An average abundance estimate for all surveys combined is 2,749 (CV = 0.27) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

Short-Finned Pilot Whale, Northern Gulf of Mexico Stock

The short-finned pilot whale is distributed worldwide in tropical to warm waters (Leatherwood and Reeves 1983). Sightings of these animals in the northern Gulf of Mexico occur primarily along the continental shelf and continental slope (Mullin et al. 1991; Southeast Fisheries Science Center, SEFSC, unpublished data). Short-finned pilot whales were seen in all seasons during recent seasonal GulfCet aerial surveys of the northern Gulf of Mexico during 1993-1995 (Davis et al., in preparation). An average abundance estimate for all surveys combined is 353(CV = 0.89) (Hansen et al. 1995). This species is not listed under the Endangered Species Act.

(5) The type of incidental taking authorization that is being requested (i.e., takes by harassment only; takes by harassment, injury and/or death) and the method of incidental taking;

The intent is to conduct the study so that it should result in no taking of marine mammals. If there is, it would be incidental takes by harassment only.

(6) By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in paragraph (a)(5) of this section, and the number of times such takings by each type of taking are likely to occur;

We anticipate "no take" of any species of marine mammals.

(7) The anticipated impact of the activity upon the species or stock;

Depending upon ambient conditions and the sensitivity of the receptor, underwater sounds produced by acoustic operations may be detectable a substantial distance from the activity. Any sound that is detectable is (at least in theory) capable of eliciting a disturbance reaction by a marine mammal or of masking a signal of comparable frequency. An incidental harassment take is presumed to occur when mammals in the vicinity of the acoustic source (or vessel) react to the generated sounds or visual cues.

When the received levels of noise exceed some behavioral reaction threshold, cetaceans will show disturbance reactions (Richardson et al., 1995). The levels, frequencies, and types of noise that will elicit a response vary between and within species, individuals, locations, and seasons. We anticipate little or no behavioral disturbance and no lasting effects on marine mammals from our proposed activities.

Hearing damage is not expected to occur as a result of this project. While it is not known whether a marine mammal very close to a sound source of modest power would be at risk, a temporary threshold shift (TTS) is a theoretical possibility (Richardson et al., 1995).

(8) The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses;

No impact anticipated.

(9) The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat;
No impact anticipated.

(10) The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved;

No impact anticipated.

(11) The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance;

(1) The smallest possible sources have been selected to minimize the chances of incidental harassment.

(2) To avoid potential incidental harassment of, or injury to, marine mammals, safety zones, (zone of impact), will be established and monitored during daylight hours. Whenever the distance between the seismic source(s) and a marine mammal becomes closer than the assigned safe distance, the USGS will shut down the seismic source.

(3) A zone of impact for the GI or water gun will be set at 30 meters and 20 meters for the Huntec boomer system, the Edgetech 512I and the Data Sonics SIS 1000.

(4) For mysticetes and odontocetes operations will cease when these mammals approach a zone of impact of 30 meters for the GI or water gun and 20 meters for the Huntec, Edgtech 512I sub-bottom profiler and SIS-1000 sidescan system.

(5) For pinnipeds (seals and sealions): if the research vessel approaches a pinniped, a safety radius of 20 m around the boomer, or sidescan fish and 30 m around the air gun will be maintained from the animal(s). However, if a pinniped approaches the seismic source, the USGS will not be required to shut it down. Experience indicates that pinnipeds will come from great distances to scrutinize seismic-reflection operations. Seals have been observed swimming within air gun bubbles, 10 m (33 ft) away from active arrays. More recently, Canadian scientists, who were using a high-frequency seismic system that produced sound closer to pinniped hearing than will the USGS sources, describe how seals frequently approached close to the seismic source, presumably out of curiosity. Therefore, because pinnipeds indicate no adverse reaction to seismic noise, the above-mentioned mitigation plan is proposed. In addition, the USGS will gather information on how often pinnipeds approach the sound source(s) on their own volition, and what effect the source(s) appears to have on them.

(6) During seismic-reflection survey operations, the ship's speed will be 4 to 5 knots so that when the seismic sources are being discharged, nearby marine mammals will have gradual warning of the ship's approach and can move away.

(7) The USGS will have trained marine mammal observers onboard who will have the authority to stop seismic operations whenever mammals enter the zone of impact.

(12) Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses.

We will not be operating in or near Artic waters.

(13) The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding. Guidelines for developing a site-specific monitoring plan may be obtained by writing to the Director, Office of Protected Resources; and

Trained marine mammal observers will be employed to monitor the zone of impact during daylight hours. Observers will call for system shut downs when/if marine mammals enter the zone of impact. Observers will monitor work areas for 30 minutes prior to the start up of seismic systems to ensure that no mammals are in the area. New surveys will not be started during night time hours when visibility is poor and the zone of impact cannot be observed for 30 minutes prior to start up. Because of the short zones of impact one trained observer will be on watch at all times during daylight hours.

Data to be recorded during seismic-reflection operations include what the weather conditions are like, such as Beaufort Sea state, wind speed, cloud cover, swell height, precipitation and visibility. For each mammal sighting the observer will record the time, bearing and reticule readings, species, group size, and the animal's surface behavior and orientation.

Observers will instruct geologists to shut down all active seismic sources whenever a marine mammal enters a safety zone.

(14) Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

The USGS is collaborating with the ChevronTexaco Joint Industry Proposal for Gulf of Mexico Gas Hydrate Drilling in order to eliminate or reduce their need to conduct a similar seismic- reflection survey in the same work area.

References

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Richardson, W. J., C.R. Greene Jr., C.I. Malme and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press. San Diego, CA. 576 p.

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Caldwell and Caldwell (1989)

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Jefferson et al (1992)

Heyning (1989)

Davis et al (in preparation)

Blaylock and Hoggard (1994)

Perrin et al (1987, 1994)

Perrin and Hohn, (1994)

Perrin and Gilpatrick (no date)

Miyazaki and Perrin (1994)

Perrin and Mead (1994)

Mullin et al (1994)

Perryman et al (1994)

Attachment 1

UNITED STATES
DEPARTMENT OF THE INTERIOR

MINERALS MANAGEMENT SERVICE

GULF OF MEXICO REGION
(AREAS IN GULF AND ATLANTIC OCS)

APPLICATION FOR PERMIT TO CONDUCT GEOLOGICAL OR GEOPHYSICAL EXPLORATION FOR MINERAL RESOURCES OR SCIENTIFIC RESEARCH IN THE OUTER CONTINENTAL SHELF

(Section 11, Outer Continental Shelf Lands Act of August 7, 1953, as amended on September 18, 1978, by Public Law 95-372, 92 Statute 629, 43 U.S.C. 1340; and 30 CFR Part 251)

________*U.S. Geological Survey (Deborah R. Hutchinson)*_________
Name of Applicant

________*Quissett Campus, 384 Woods Hole Rd*.________________
Number and Street

________*Woods Hole, MA 02543*____________________________
City, State, and Zip Code

________*U.S. Geological Survey* ____________________________
Name of Service Company or Purchaser
(if different from above)

Application is herein made for the following activity: (check one)

_______Geological exploration for mineral resources

_______Geological scientific research

_______Geophysical exploration for mineral resources

____√___Geophysical scientific research

Submit: Original, two copies, and one public information copy.

To be completed by MMS

Permit Number: _________________________ **Date:** _______________________

MMS-327 Page 5 (July 2000)

A. General Information

1. The activity will be conducted by:

___*U.S. Geological Survey*________	For _____________*N/A*________________
Service Company Name	Purchaser(s) of the Data
384 Woods Hole Rd.	
___*Woods Hole, MA 02543*_______	________________________________
Address	Address
508-548-8700 (phone)	
___*508-457-2310 (fax)*__________	________________________________
Telephone/FAX Numbers	Telephone/FAX Numbers
___dhutchinson@usgs.gov________	________________________________
E-Mail Address	E-Mail Address

2. The purpose of the activity is: _________ Mineral exploration

____√____ Scientific research

3. Describe the environmental effects of the proposed activity, including potential adverse effects on marine life and what steps are planned to minimize these adverse effects (use continuation sheets as necessary):

Scientific Activity: *The proposed activity is to collect high-resolution seismic reflection data in the north-central Gulf of Mexico that will be used to (a) characterize the geologic framework; (b) map the distribution of acoustic indicators of gas hydrate; (c) tie to pre-existing public-domain seismic data; (d) tie to available well information; and (e) select potential future gas hydrate-drill sites.*

Environmental Effects: *The most significant environmental impact of this work is the possible incidental harassment of marine mammals by the noise generated by the acoustic sound sources. The USGS has already submitted to NOAA/National Marine Fisheries Service a request for an Incidental Harassment Authorization related to this survey. Based on the amplitude and frequency spectra of the seismic sources utilized (low energy, high frequencies), no taking of marine mammals is expected. Incidental harassment, while not impossible, is considered unlikely. Trained mammal observers will be on board the research vessel to monitor whale observations.*

4. The expected commencement date is: ____*29 April, 2003*________________________________.

The expected completion date is: ______*16 May, 2003*________________________________.

5. The name of the individual in charge of the field operation is: __*Deborah R. Hutchinson or Patrick Hart*_____.

May be contacted at: *At Sea – c/o R/V Gyre, Desmond Rolf, TAMU Marine Operations Facility*

__*Galveston, TX.*   *Email: gyreops@tamug.tamu.edu*

MMS-327 Page 6 (July 2000)

Telephone (Local) ___*409-740-4469*___________ (Marine) __*011-874-150-4765 (Inmarsat)*____.

Radio call sign __*US NODC Code: 32GY*__.

6. The vessel(s) to be used in the operation is (are):

Name ___*R/V Gyre*___________________ Registry number ______________________________

Registered owner ______________________*US Navy*______________________________.

7. The port from which the vessel(s) will operate is: ____*Galveston, TX*_________________________.

8. Briefly describe the navigation system (vessel navigation only): ______________________________

_______*Differential GPS into an integrated Navigation system*____________________________.

____

B. Complete for Geological Exploration for Mineral Resources or Geological Scientific Research

1. The type of operation(s) to be employed is: (check one)

(a) __________ Deep stratigraphic test, or (b) __________ Shallow stratigraphic test with proposed total depth of ___________, or (c) __________ Other ______________________________________

2. Exact geographic coordinates of proposed test(s) (attach a page-size plat(s)): ____________________

____

C. Complete for Geophysical Exploration for Mineral Resources or Geophysical Scientific Research

1. Proposed location of the activity (attach a page-size plat(s)): *North-central Gulf of Mexico (see attached)*

2. The type(s) of operation(s) to be employed is (are): ______*High-resolution seismics*______________.

____.
(Seismic, gravity, magnetic, etc.)

3. The instrumentation and/or technique(s) to be used in the operation(s) is (are): *Huntec boomer; Edgetech 512I profiler; 15-cu. in water gun; 35-cu. in GI Gun; DataSonic SIS-1000 Side-scan Sonar*______________.
(Air gun, sparker, etc.)

4. Explosive charges will ______ will not __√___ be used. If applicable, indicate the type of explosive and maximum charge size (in pounds) to be used:

Type ______________________ Pounds ______________ Equivalent Pounds of TNT ______________

MMS-327 Page 7 (July 2000)

D. Proprietary Information Attachments

Use the appropriate form on page 9 for a "geological" permit application or the form on page 10 for a "geophysical" permit application. You must submit a separate Form MMS-327 to apply for each geological or geophysical permit.

E. Certification

I hereby certify that foregoing and attached information are true and correct.

SIGNED ____ **DATE** ______________________

TITLE ____

===

TO BE COMPLETED BY MMS

Permit No.__________________ **Assigned by** ________________________________ **Date** ____________
of MMS

This application is hereby:

a. _____ Approved

b. _____ Returned for reasons in the attached

The approved permit is:

a. _____ Attached

b. _____ Will be forwarded at a later date

SIGNED ____________________________ **TITLE** ___Regional Supervisor___ **DATE** ____________

MMS-327 Page 8 (July 2000)

Section D Proprietary Information Attachment

Required for an Application for
Geological Permit

1. Brief description of method of shallow drilling or sampling: ___________***N/A***___________________________.

____

2. Brief description of shallow drilling or sampling equipment to be used: _________________________________

____

____

3. Number of boring or sample locations to be occupied: ____

____

4. Navigation system or method to be used to position sample locations: ______________________________

____

____

5. Method of sample analyses, storage, and handling: ____

____

6. Description and list of the final analyzed and/or processed data which will result from operations under the proposed activity: ____

____

____

7. Estimated date on which samples, logs, and analyzed and/or processed data will be ready for inspection:

____

8. Attach map(s), plat(s), and chart(s) (preferably at a scale of 1:250,000) showing latitude and longitude, scale, specific block numbers, specific boring sample locations, and total number of borings or samples proposed.

Section D Proprietary Information Attachment
Required for an Application for
Geophysical Permit

1. Brief description of the energy source and streamer (receiving array): ________________________________

____

____

2. Total energy output per impulse: ____

3. Number of impulses per linear mile: ____

4. Towing depth of the energy source: ____

5. Towing depth of the streamer: ____

6. Navigation system or method to be used to position shotpoint locations: ______________________

____

____

. Area of activity and total number of line miles proposed: ___________________________________

8. Description and list of the final processed data which will result from operations under the proposed activity: ____

____

9. Estimated date on which processed data will be available for inspection: ______________________

____

10. Attach map(s), plat(s), and chart(s) (preferably at a scale of 1:250,000) showing latitude and longitude, scale, specific block numbers, specific tract lines with line identifications, and the total number of line miles proposed.

Attachment 2

UNITED STATES
DEPARTMENT OF THE INTERIOR

MINERALS MANAGEMENT SERVICE

GULF OF MEXICO REGION
(AREAS IN GULF AND ATLANTIC OCS)

NONEXCLUSIVE USE AGREEMENT FOR SCIENTIFIC RESEARCH IN THE OUTER CONTINENTAL SHELF

A. State the time and manner in which data and information resulting from the proposed activity will be made available to the public for inspection and reproduction, such time being the earliest practicable time.

One year from the date of the survey, a data report will by released as a U.S. Geological Survey Open-File (Digital Data) Report. This will include all navigation, cruise statistics, and SEG-Y field data from this cruise. Additional professional presentations and journal publications will occur for up to 2-3 years following the cruise.

B. *US Geological Survey* (applicant) agrees that the data and information resulting from the proposed activity will not be sold or withheld for exclusive use.

____
(Signature of Applicant)

Deborah R. Hutchinson .
(Type or Print Name of Applicant)

Research Geologist .
(Title)

22 April, 2003 .
(Date)

Submit: Original, two copies, and one public information copy.

MMS-327 Page 11 (July 2000)

Appendix 4: Science Roster

Name	Function	Affiliation
Patrick Hart	Co-chief Scientist	USGS, Menlo Park
Deborah Hutchinson	Co-chief Scientist	USGS, Woods Hole
Larry Kooker	Electronics Technician	USGS, Menlo Park
Mike Boyle	Electronics Technician	USGS, Menlo Park
Tom O'Brien	Electronics Technician	USGS, Woods Hole
Graham Standen	Huntec Technician	Geoforce Consultants, Ltd.
Hal Williams	Mechanical Technician	USGS, Menlo Park
Walt Olson	Mechanical Technician	USGS, Menlo Park
Brandon Dugan	Watch	USGS, Woods Hole
Lori Hibbeler	Watch	ECO/USGS, Menlo Park
Seth Ackerman	Watch/GIS	ECO/USGS, Woods Hole
Jen Dougherty	Watch/GIS	ISI/USGS, Menlo Park
Ray Sliter	Watch/Processing	USGS, Menlo Park
Erika Geresi	Watch/Processing	Univ. Mississippi
Mary Jo Barkaszi	Mammal Observer	ECOES
Richard Holt	Mammal Observer	ECOES

Appendix 5: Ship Roster and Specifications

Name	Function
Dana O. Dyer III	Captain
Gary Spitler	First Mate
Joseph Hebert	Second Mate
Dallas Francis	AB Seaman
Carlos Cano	AB Seaman
Jerry Rogers	Chief Engineer
David Fountain	Oiler
Claude Walker	Steward
Robert Eppling	Messman
Bill Green	Science/Deck Engineer

R/V Gyre Ship Specifications

Length: 55.5 m
Breadth: 11 m
Freeboard: 1.4 m
Draft: 4 m
Year Built: 1973
Operator: Texas A&M University
Gross Tonnage: 292 GRT
Fuel: 278 m^3
Wet Lab Area: 15 m2
Dry Lab Area: 81 m2
Free Deck Area: 181 m2
Range: 8,000 nm
Cruising Spd: 9.5 kts
Max Spd: 11.5 kts
Endurance: 35 days
Ship Crew: 9-14
Science Crew: 23
Airconditioned: yes

Appendix 6: Photo Gallery

(Not complete)

ATTACHMENT 2

Report to Anadarko JIP

(see file Anadarko_Summary.pdf)

ATTACHMENT 3

Congressional Briefing Report

16 January, 2003

(1) 10:00 a.m. **Senator Conrad Burns Staff,**
SD-187 (Dirkson Senate Office Bldg)

Staffers Attending:

Myron Nordquist - Legislative Counsel
Chris Lee - Deputy Legislative Counsel
Christine Heegem - Legislative Assistant; handles energy, environment and natural resource issues (attended only about 20 min)
Eric Bovian - Communications

Briefers Attending

Deborah Hutchinson (USGS, Project Chief, Gas Hydrates)
Frances Pierce (USGS, Program Coordinator, Energy Resources Program)
Tim West (USGS, Congressional Affairs)
Edith Allison (DOE, Headquarters, Office of Natural Gas and Petroleum Technology)
Barbara Moore (NOAA/NURP, Director of Research)
Diana Martinez-Fonts (NOAA, Congressional Affairs)

Purpose of Briefing

"Primer" on Gas Hydrates, i.e., an overview of hydrates and related energy/hazard/climate issues; Sen. Burns is potentially interested in methane hydrates because he would like to find alternatives to foreign oil for meeting US energy needs. Myron Nordquist requested this briefing through Barbara Moore.

Outline of Material Covered: See Attachment 1

Handouts: See Attachment 1

Comment:

This briefing lasted approximately 90 minutes and was full of questions, primarily from Myron Nordquist. These questions spanned energy policy, data clarifications, and general understanding of hydrates. There was some discussion about how involved the Russians were in the International Coordination and the amount of gas hydrate resources in Russia. More than once Myron expressed how interesting this all was. He also repeated the concerns expressed by Sen. Burns (with reference to concerns by Senator Stevens from Alaska) that there may be political will (perhaps independent of economic and technologic considerations) to look at alternative energy like hydrates rather than being dependent on oil from countries with fundamentalist Muslim governments.

Chris Heegem, the staffer most likely to be familiar with hydrates, could only stay about 20 minutes, due to Appropriations hearings on the Senate Floor. We rearranged the presentation to include Edie's pieces on interagency coordination, budgets, and legislation, for Chris before she had to leave.

Action Items:

Map of global hydrates showing 200-nm EEZ, especially Arctic (Debbie and Barbara)
Contents from volumes from Japan (Yokohama) gas hydrates meeting (Edie)
Page size copies of slides rather than 2/page (Barbara)

(2) 1:00 p.m. **House Subcommittee on Energy and Mineral Resources**
Longworth 1327 (Longworth House Office Building)

Staffers Attending:

Jack Belcher, Staff Director,
John Rishel, Legislative Staff
Isaac ??, Intern

Briefers Attending

Deborah Hutchinson (USGS, Project Chief, Gas Hydrates)
Frances Pierce (USGS, Program Coordinator, Energy Resources Program)
Tim West (USGS, Congressional Affairs)
Edith Allison (DOE, Headquarters, Office of Natural Gas and Petroleum Technology)
Barbara Moore (NOAA/NURP, Director of Research)

Purpose of Briefing

"Primer" on Gas Hydrates, i.e., an overview of hydrates and related energy/hazard/climate issues; The Subcommittee on Energy and Minerals was involved in the development of the Methane Hydrates Research and Development Act of 2000. USGS requested this briefing because we were preparing materials for the Senator Burns meeting earlier in the day.

Outline of Material to be Covered: See Attachment 1

Handouts: See Attachment 1

Comment:

Like the morning briefing, this one lasted about 1½ hours. Jack Belcher was the active participant, asking the most questions, although the intern, Isaac, also asked for clarifications. Most of the discussion occurred in the last half hour, after the formal slides were covered. The questions tended to focus more on the technology and the international participants. Jack Belcher seemed to like the idea of having an oversight hearing on gas hydrates to raise awareness of hydrates issues.

Action Items: None.

Attachment 1

Material Covered and Handouts

16 January, 2003

Outline of Material Covered:

(dh – D. Hutchinson; bm – B. Moore; ea – E. Allison)

A. What are they? (dh)

B. Where are they found? (dh)

C. Where do they come from (How are they generated)? (dh)

D. How much (quantities)? (dh)

E. Why do we care?

1. potential source of fuel/energy (dh)
2. hazard in oil and gas drilling (dh)
3. chemical input to the oceans/atmosphere (climate implications) (dh/bm)
4. unique ecosystems associated with seeps and hydrates (bm)

F. What's the current state of knowlege regarding these issues (dh and bm)

G. Who are the players; how we are organized to deal with these issues in the US Govt?

1. legislation (ea)
2. interagency coordinating committee (ea)
3. budgets (ea)

USGS Handouts

A. General Information

11x17 map - Global Inventory of Natural Gas Hydrate Occurrence
Fact Sheet – Natural Gas Hydrates – Vast Resource, Uncertain Future
Fact Sheet - Gas Hydrate in Ocean Sediment - curiosity? energy resource? hazard?
Fire from Ice (news feature from Nature, August, 2002)
EOS Article - Fishing trawler nets massive "catch" of Methane Hydrates
US News and World Report - Report on Mallik Drilling
Fact Sheet - USGS Research in Gas Hydrates
Fact Sheet - Gas Hydrate Laboratory Research - the GHASTLI experiments

B. More Detailed Papers

Collett - Energy Resource Potential of natural gas hydrates
Dillon - Gas Hydrate in the Ocean Environment
Kvenvolden and Lorenson - The Global Occurrence of Natural Gas Hydrate
Hovland and Gudmestad - Potential Influence of Gas Hydrates on Seabed Installations

DOE Handouts

A. Interagency Coordination on Methane Hydrate R&D

B. Report of the Methane Hydrate Advisory Committee on Methane Hydrate Issues and Opportunities

NOAA Handouts

A. NOAA/NURP Research Program (Brochure)

ATTACHMENT 4

Copies of Selected Abstracts

HYDROCARBON GASES FROM GIANT PISTON CORES IN THE NORTHERN GULF OF MEXICO: FROM SEAFLOOR VENTS TO MINIBASINS

T. Lorenson (1), J. Dougherty (1), and J. Flocks (2)

(1) U.S. Geological Survey, 345 Middlefield Rd., MS-999, Menlo Park, CA 94025 (tlorenson@usgs.gov)
(2) U.S. Geological Survey, 600 4th Street S., St. Petersburg, FL 33701

Hydrocarbon gases and carbon dioxide extracted from sediment cores from the northern Gulf of Mexico were studied to constrain the possible occurrence and source of gas that may form gas hydrate. Three sample types were analyzed; gas from dissociated gas hydrate, dissolved gas in sediment, and free gas evolved from sediment collected from gas voids in the core liner.

Gas hydrate was recovered from two sites; however, only samples from one site, in the thalweg of Mississippi Canyon within lease area MC802 was preserved for analysis. The quality of the gas hydrate recovered was poor due because the time for core recovery approached two hours. Methane, ranging from 95.0 to 99.5%, is the principal gas in the gas hydrate with CO_2 ranging from 0.16% to 4.0%. High molecular weight hydrocarbon gases; ethane, propane and isobutane are found in concentrations exceeding 1000 parts per million suggesting that both structure I and structure II gas hydrate are present.

Sediment collected near the summit of a diapiric structure on Kane Spur within lease area MC853, (34-km east of MC802), contained visible oil and hydrocarbon gases of thermogenic origin. Sediment from MC802 contained some proportion of hydrocarbon gases of likely thermogenic origin, but at much lower concentrations than at MC853. Free gas from sediment at MC853 was also composed of mainly thermogenic hydrocarbons. Sediment gases from other areas (Tunica Mound, Bush Hill, and areas in and flanking Mississippi Canyon) were composed mainly of microbial methane and traces of thermogenic hydrocarbons.

Gas Hydrate in the Northern Gulf of Mexico: New Insights Learned from Giant Piston Coring

Thomas Lorenson[1] (tlorenson@usgs.gov), William J. Winters[2] (bwinters@usgs.gov), Charles Paull[3] (paull@mbari.org), William Ussler III[3], and the PAGE 127 Shipboard Scientific Party

[1]U.S. Geological Survey, 345 Middlefield Rd., MS-999, Menlo Park, CA 94025

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The northern Gulf of Mexico hosts numerous seafloor (<7m subbottom) occurrences of gas hydrate. The seafloor is dominated by salt-tectonic basin structures, high sedimentation rates (about 40 cm/kyr), and complex late Neogene stratigraphy with common seafloor failures. Natural oil and gas seeps are abundant, usually associated with fault conduits resulting in numerous hydrocarbon vents, often capped by gas hydrate when the seeps are within the hydrate stability zone. While gas hydrate is relatively common at the seafloor, the lack of bottom simulating reflections on seismic records suggest that gas hydrate at depth is largely absent. Thus, it is unknown if there are significant gas hydrate accumulations in reservoir sediments away from faults. To address this question a cruise was conducted with the IMAGES (International Marine Past Global Changes Study) and PAGE (Paleoceanography of the Atlantic and Geochemistry) programs aboard the *Marion Dufresne* in July 2002.
Eighteen giant piston cores, up to 38-m long, and four giant box cores up to 9-m long, were recovered along seismic reflection transects in widely different geologic environments in water depths ranging from about 600-1300 m. The transects were designed to extend from known seafloor gas hydrate occurrences across the adjacent basin to background sediments away from any gas venting sites. Gas hydrate was recovered in four cores from previously known venting sites in subbottom depths of about 3 to 9-m, but was not found in adjacent basins. Our results confirm the presence of gas hydrate in near-seabed sediments in the northern Gulf of Mexico.

Gas Hydrate Occurrence in the Northern Gulf of Mexico Studied with Giant Piston Cores: From Seafloor Vents to Minibasins

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The seafloor (<7m subbottom) of the northern Gulf of Mexico contains numerous occurrences of gas hydrate. The topography and recent stratigraphy of the seafloor is complicated by salt-tectonic structures, frequent sediment failure scars, and high sedimentation rates (up to 40 cm/kyr in places). The abundant natural oil and gas seeps are often capped by gas hydrate when the seeps occur within the hydrate stability zone. While gas hydrate is relatively common at the seafloor, seismic reflection profiles lack bottom simulating reflections. Thus, it is unknown if there are significant gas hydrate accumulations within the sediment sections away from the seep localities. To address this question a cruise was conducted with the IMAGES (International Marine Past Global Changes Study) and PAGE (Paleoceanography of the Atlantic and Geochemistry) programs aboard the *Marion Dufresne* in July 2002. Seventeen giant piston cores, up to 38-m long, and four giant box cores up to 9-m long, were recovered along seismic reflection transects in water depths ranging from about 600-1,300 m in widely different geologic environments. The transects extended from known seafloor gas hydrate occurrences or fluid venting sites into the adjacent basin up to 7 kilometers away from the known venting site. Gas hydrate was recovered in four cores near two previously known venting sites in subbottom depths of about 3 to 9-m, but was not found in adjacent basins. Our results confirm the presence of gas hydrate at near-seabed sediments in the northern Gulf of Mexico; however, geochemical analyses of sediment porewater within 1-15 km from known vent sites indicate that gas hydrate deposits may not be pervasive in the areas surveyed.